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Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

REMEDIAL INVESTIGATION REPORT

Sections 1 and 2

Newark Bay Study Area
Newark, New Jersey

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CONTENTS

TABLES

FIGURES

APPENDICES

TO BE UPDATED

ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
AOC	Administrative Order on Consent
Arcadis	Arcadis U.S., Inc.
Bay	Newark Bay
BAZ	biologically active zone
BERA	baseline ecological risk assessment
BHHRA	baseline human health risk assessment
BIC	benthic invertebrate community
bss	below sediment surface
CARP	Contamination Assessment and Reduction Project
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cfs	cubic feet per second
cm	centimeter
CPG	Cooperating Parties Group
CSM	Conceptual Site Model
CSO	combined sewer outfall
cy	cubic yards
DASS	Diamond Alkali Superfund Site
DEAR	Data Evaluation and Analysis Report
FDR	Field and Data Report
FS	Feasibility Study
GSH	Glenn Springs Holdings, Inc.
HDP	Harbor Deepening Project
HRA	Harbor Ambient Sediment Sampling Project
HRT	Harbor Sediment Trackdown Sampling Project
HydroQual	HydroQual, Inc.
kHz	kilohertz
LPR	Lower Passaic River
LPRSA	Lower Passaic River Study Area

NBSA	Newark Bay Study Area
NJ	New Jersey
NGVD29	National Geodetic Vertical Datum of 1929
NJDEP	New Jersey Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
NY	New York
NYSDEC	New York State Department of Environmental Conservation
OCC	Occidental Chemical Corporation
OSI	Ocean Surveys, Inc.
OU	operable unit
OU1	Operable Unit 1
OU2	Operable Unit 2
OU3	Operable Unit 3
OU4	Operable Unit 4
OU2 Site	lower 8.3 miles of the Lower Passaic River
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-*p*-dioxin
PCDF	polychlorinated dibenzofuran
Phase III QAPP	Newark Bay Study Area Phase III Sediment Investigation Quality Assurance Project Plan Amendment
POTW	publicly owned treatment works
ppth	parts per thousand
PRP	Potentially Responsible Party
PRSA	Passaic River Study Area
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
REMAP	Regional Environmental Monitoring and Assessment Program
RI	Remedial Investigation
RIWP	Remedial Investigation Work Plan

ROD	Record of Decision
SOW	Statement of Work
SQT	sediment quality triad
SSO	storm sewer outfall
SVOC	semivolatile organic compound
TEPH	total extractable petroleum hydrocarbons
Tierra	Tierra Solutions, Inc.
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound

1 INTRODUCTION

The Diamond Alkali Superfund Site (DASS) was added to the Superfund National Priorities List on September 21, 1984 because of contaminants present at the site (Figure 1-1). Four different operable units (OUs) are associated with the site (Figure 1-2): the former manufacturing plant and surrounding properties at 80 and 120 Lister Avenue (Operable Unit 1 [OU1]), the lower 8.3 miles of the Passaic River (Operable Unit 2 [OU2] Site), the Newark Bay Study Area (NBSA; Operable Unit 3 [OU3]), and the lower 17 miles of the Passaic River (Operable Unit 4 [OU4]; Lower Passaic River Study Area [LPRSA]; U.S. Environmental Protection Agency [USEPA] 2016a).

Pursuant to the Administrative Order on Consent (AOC) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; Index 02-2004-2010; USEPA 2004), Glenn Springs Holdings, Inc., (GSH), on behalf of Occidental Chemical Corporation (OCC; the successor to Diamond Shamrock Chemicals Company [formerly known as Diamond Alkali Company]), has conducted a Remedial Investigation (RI) for the NBSA. The findings of the NBSA RI are the subject of this RI Report.

1.1 Site Setting and Study Area Description

1.1.1 Newark Bay Study Area

Newark Bay (Bay) is a 6.3-square-mile enclosed embayment on the western side of the New York/New Jersey (NY/NJ) Harbor Estuary. The Bay is adjacent to four large cities (Newark, Elizabeth, Bayonne, and Jersey City), and is fringed on its western side by port facilities, industrial facilities, and the Newark Liberty International Airport. On its northern side, the Hackensack and Passaic Rivers flow into the Bay, while on the southern side, the Bay is connected to NY Harbor (NY) and Raritan Bay (NJ) through two tidal straits: the Kill van Kull and Arthur Kill, respectively. The NBSA has been defined as the Bay and portions of key tributaries, including the Hackensack River, Arthur Kill, and Kill van Kull (Figure 1-2). The Passaic River is not included in the definition of the NBSA, as it is presently being investigated as a separate OU (OU4). However, investigations of the Passaic River and NBSA OUs are being conducted in a comparable manner and with careful consideration of their linkages for the purposes of CERCLA management decision-making and broader environmental management considerations.

The Bay is a partially mixed estuary, meaning that there is some density stratification of saline and fresh water (Suszkowski 1978; U.S. Army Corps of Engineers [USACE] 2007a). The typical salinity of Bay water is in the range of 10 to 20 parts per thousand (ppth), which is indicative of freshwater mixed with seawater (approximately 30 ppth). The tides in the Bay area are semi-diurnal, with a mean tide range of 5.1 feet and a spring tide range of 6.1 feet. The mean tide level is 5.9 feet above North American Vertical Datum of 1988 (USACE 1997). Tidal currents are the primary mechanism of water flow within the Bay and are strongest (both ebb and flood) in the Arthur Kill and Kill van Kull. The dominant freshwater contributions to the Bay are from the Passaic and Hackensack Rivers at the northern end of the Bay, while other freshwater sources to the Bay include smaller tributaries like the Elizabeth River, Peripheral Ditch, and Piersons Creek, among others (Figure 1-1). Annual flow computations by Blumberg et al. (1999) show that approximately 60% of annual flows into the Bay come from the Kill van Kull and 34% come from the Hackensack and Passaic Rivers combined, while net discharge to the Raritan Bay occurs

through the Arthur Kill. Salinity is highest and density stratification is weakest in the Kill van Kull due to high volume exchange with NY Harbor (Suszkowski 1978).

The Newark Basin, in which the NBSA is located, is underlain by sedimentary rocks (sandstones, shales, limy shales, and conglomerates), igneous rocks (basalt and diabase), and metamorphic rocks (schists and gneiss). Sediments found on the bottom or just below the bottom of the Bay are mostly fine-grained within the range of silt and clay-sized particles (USACE 1997). The pattern of sediment types (sand/gravels versus silt/clays) is indicative of fluvial sediment input at the northern end of the Bay and tidal exchange sedimentation at the southern end. The physiography and geology of the NBSA is discussed in further detail in Section 3.1.

Hydrodynamics within the Bay are influenced primarily by three inter-related physical forces: 1) astronomical forcing (tides), 2) tributary flows from the Passaic and Hackensack Rivers, and 3) local and regional meteorological events (wind and storm effects) (Herrington et al. 2002; Wakeman 2006). These primary influences are responsible for the variations in hydrodynamic and sediment transport characteristics within the system (Herrington et al. 2002). Hydrodynamics of the NBSA are described in further detail in Section 3.3.

1.1.2 Environmental History, Development, and Use of the Newark Bay Study Area

The Bay is central to one of the most urbanized and industrialized areas in the United States. It has experienced more than 2 centuries of environmental degradation attributable to many factors, including shoreline and land development (USACE 2006a), wetlands/habitat loss, garbage and sewage disposal, dredging and dredged material disposal, and releases of contaminants from a variety of sources and locations (Iannuzzi et al. 2002).

The environmental history of Newark Bay parallels the development of the New York City metropolitan area. Most shipping and economic development in the 19th century clustered around Manhattan and Brooklyn, but as the pace of development quickened in the first half of the 20th century, the Bay eventually supplanted Manhattan as the primary port by the middle of the 20th century. Over that period of development, approximately 80 to 90% of the pre-existing shoreline of the Bay was developed and ecological habitats correspondingly diminished (Iannuzzi et al. 2002; USACE 2009a).

Newark and Elizabeth (known in its early history as Elizabethtown and Elizabethport), much like surrounding communities, started as small towns surrounded by farms, forest, and wetlands (Hassler 1844). By the 1840s, railways bisected wetlands and connected Newark to Jersey City and Elizabeth, setting the pre-conditions for future industrial development. Newark was home to several chemical companies producing various chemical products and raw materials by 1850 (Cunningham 1954; Zdepski 1992). By 1900, Newark was the largest industrial-based city in the United States, with well-established industries, including petroleum refining; shipping; tanneries; creosote wood preservers; metal recyclers; and manufacturers of materials, including rubber, rope, textiles, paints and dyes, pharmaceuticals, raw chemicals, leather, and paper products (Meyers 1945; Cunningham 1954, 1966; Brydon 1974; Halle 1984; MacRae's 1986; Galishoff 1988). By the early 20th century, housing developments covered most of the Bayonne peninsula, and the cities of Newark and Elizabeth on the west side were greatly expanded as the growing industrial manufacturing complex in the Newark region replaced agriculture and large

numbers of people moved to the area. Commercial use of local waterways expanded between 1920 and 1950, driven by demands associated with World Wars I and II (Squires 1981). The Bay continued to evolve into what is now a highly modified, major shipping port.

The development of the Bay port system required extensive land development, achieved through "reclamation" of the meadowlands (wetlands) along the Bay and the Hackensack River during the 20th century. As the area's population and industrial development grew, transportation needs increased, and a large network of roads, bridges, airports, and port facilities was constructed. Today, Newark – the largest city in New Jersey – is a trade and transportation center. One of Newark's important functions as a transportation center is the transfer of goods from cargo vessels in the Bay ports to the many railroad and truck lines that serve the region and beyond. Land use along the northern, western, and southern shoreline of the Bay is high-density commercial and industrial/commercial development. A highly developed network of highways, combined sewer overflows, storm sewer outfalls, and publicly owned treatment works also exist within the Bay and its watershed (Mueller et al. 1982).

Industrialization of the Bay was facilitated by development of navigational channels in the NY/NJ Harbor Estuary starting in the mid-1800s through channel deepening and widening by the USACE New York District (see Figure 1-2 for current navigation channel system). Table 1-1 presents the Bay's history of dredging, navigation channel widening, and wetlands alteration. Bathymetry surveys have been conducted since the early 1900s by the National Oceanic and Atmospheric Administration (NOAA) and USACE, and historical nautical charts prepared by the NOAA illustrate the shaping of the Bay. Bathymetry surveys are discussed in further detail in Section 2.2.5.

The depth and width of the navigational channels have grown continually since the early 1900s (USACE 2006a), although channels in some adjacent water bodies (e.g., the Lower Passaic River [LPR] and Hackensack River) are no longer maintained to their previously authorized depths. The navigation channel in the Bay north of the port channels is not maintained to previously authorized depths, even though it is still subject to large vessel traffic (e.g., wastewater treatment sludge barges). Substantial maintenance dredging of the existing channels is required. During the most recent maintenance dredging (2016), approximately 285,000 cubic yards (cy) of material were removed from critically shoaled areas of the Port Newark approach channels. Currently, channel conditions are being monitored. The next maintenance dredging contract is expected to be awarded in 2018 (USACE 2018).

It is important to distinguish the annual maintenance dredging from construction dredging, which may be considerably larger but occurs only once for any given project modification and typically removes parent bed material, whereas maintenance dredging removes newly accumulated material. In September 2016, the USACE completed the Harbor Deepening Project (HDP). It included deepening in the Kill van Kull, Arthur Kill, Elizabeth Channel, and the southern portion and middle reaches of the Bay (Figure 1-3) to accommodate large post-Panamax ships, which have drafts of 48 feet or more. With the completion of the project, 50 feet of water access is available in the major channels in NY Harbor and the Bay, including the channels leading to the terminals in the NBSA (USACE 2016). The estimated total volume of dredged material removed as a result of the entire project (including NY Harbor and the NBSA), was 52,000,000 cy. Dredged material was placed at the Historic Area Remediation Site (located offshore in the Atlantic Ocean adjacent to the NY/NJ Harbor Estuary) or was beneficially reused for grading/closure materials, marsh restorations, and artificial reef development (USACE 2004a, 2013).

A present land use map of the NBSA is presented on Figure 1-4. Human use of the NBSA is primarily industrial and commercial. Recreational use is limited due to access limitations from the shoreline types (i.e., bulkhead, bridges, sheet piling, and mudflats) and surrounding urban/industrial/commercial land use. Access for recreation is through available public access areas and pleasure boating (i.e., from marinas inside and outside of the NBSA). Human use and associated exposure pathways are discussed in Section 6.1.

Ecological use is limited, particularly for nesting and foraging birds and mammals, by wetland and tributary losses, as well as shoreline coverage by bulkheads, riprap, buildings, and impervious surfaces (i.e., pavement and concrete) (Iannuzzi et al. 2002). Subtidal flats are the primary habitat areas for aquatic organisms in the Bay, with intertidal mudflats and vegetated wetlands comprising only a small portion of the overall shoreline area (Figure 1-4). Degraded structures and pilings offer some habitat for aquatic species. Shooter's Island offers some forested and wetland habitat for birds. North and south of the NBSA are extensive tidal wetlands associated with the Hackensack River and the Arthur Kill that provide wildlife habitat for birds and mammals. Despite the changing habitat conditions in the ecosystem during the 20th century, the Bay acts as a spawning ground, migratory pathway, and a nursery/foraging area for a variety of aquatic organisms. Ecological use and exposure pathways are discussed in Section 6.2.

1.2 Superfund Site History and Participation

The NBSA is part of the DASS, which was added to the Superfund National Priorities List on September 21, 1984 because of contaminants present at the site (Figure 1-1).

Four different OUs are associated with the DASS today (Figure 1-2):

- OU1: 80 and 120 Lister Avenue
- OU2: Lower 8.3 miles of the Passaic River
- OU3: NBSA
- OU4: Lower 17 miles of the Passaic River (USEPA 2016a)

In 1990, a Consent Decree was entered into by the USEPA/State of New Jersey and OCC to implement and maintain an interim remedy, documented in a 1987 Record of Decision (ROD), at 80 and 120 Lister Avenue for OU1 (United States District Court 1990). In 2007, an AOC signed by the USEPA and the Cooperating Parties Group (CPG; USEPA 2007a) to conduct an RI/Feasibility Study (FS) for OU4 (and OU2).

In 2004, the USEPA and OCC signed an AOC under CERCLA (Index 02-2004-2010; USEPA 2004) in which OCC agreed to conduct an RI/ FS for the NBSA (USEPA 2004). GSH is performing the work on OCC's behalf. The USEPA sent General Notice Letters to provide notice of potential liability in the NBSA to additional companies in 2006, 2007, 2009, and 2012 as shown in Table 1-2.

Cleanup activities performed or planned to date at the DASS include the following:

- On September 30, 1987, the Record of Decision (ROD) for OU1 was finalized. The USEPA-selected interim remedy, which was completed by 2001, included constructing slurry and flood walls, capping the properties, and pumping and treating of groundwater to reduce its migration.

- In June 2008, the USEPA and OCC signed an agreement to remove 200,000 cy of contaminated sediment from the river adjacent to OU1. Phase I was completed in 2012 and included dredging, dewatering, and offsite disposal of 40,000 cy. Phase II was intended to include removal of the remaining 160,000 cy with disposal in a confined disposal facility. Remediation of the Phase II area is being integrated with the OU2 remedy.
- In June 2012, the USEPA and CPG signed an agreement to address contaminants found at the surface of a mudflat on the east bank of the Passaic River at River Mile 10.9 in Lyndhurst, New Jersey. In 2013 and 2014, surface sediment was dredged and a cap was constructed.
- On March 3, 2016, the ROD for OU2 was finalized. The selected remedy consists of capping with sediment dredging to accommodate cap construction. The design of the OU2 remedy is underway (USEPA 2018).

The NBSA, which is the subject of this RI Report, is presently in the RI/FS process. In addition to this RI, baseline human health and ecological risk assessments (BHHRA and BERA, respectively) are being conducted for the NBSA, and the FS will follow.

1.3 Remedial Investigations

All investigation work was carried out in accordance with the USEPA-approved RI documents developed in accordance with Section B of the Statement of Work (SOW) attached to the RI/FS AOC, including the *Health and Safety/Contingency Plan* and the *Investigation Work Plan (IWP)/Sampling and Analysis Plan (SAP)/Site Management Plan (SMP)/Quality Assurance Project Plan (QAPP)* (Tierra 2005a, 2005b, respectively). The RI work is described in Section 2.

GSH has completed all investigation work needed to prepare an FS and support remedial decision-making in the NBSA. The efforts described in the USEPA-approved work plans have been completed.

This RI Report was developed based on the requirements described in Paragraph E (Scope) of the SOW attached to the RI/FS AOC, as well as USEPA guidance on the development of RIs under CERCLA (USEPA 1988). All relevant data for the various media in the NBSA that represent current conditions are included in the discussions of nature and extent (Section 4) and fate and transport (Section 5). Concurrent with USEPA review of this RI Report, GSH will prepare an FS Report.

1.3.1 Remedial Investigation Objectives

The RIs in the NBSA, designed and conducted according to the requirements specified in the RI/FS AOC and associated SOW, were developed to generate additional data that will be used to produce this RI Report, an FS Report, and ultimately support the development of a ROD for the NBSA. The NBSA AOC defined three RI-related goals that are addressed in this RI Report:

1. **Nature and Extent of Sediment Contamination:** Determine the horizontal and vertical distribution and concentrations of polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), pesticides, and metals for NBSA sediments.

2. **Risk Assessment:** Determine the primary human and ecological receptors (endpoints) of PCDD-, PCDF-, PCB-, PAH-, pesticide-, and metals-contaminated sediments in the NBSA.
3. **Source Identification:** Determine the significant direct and indirect continuing sources of PCDDs, PCDFs, PCBs, PAHs, pesticides, and metals to the sediments in the NBSA (USEPA 2004).

As described in the RI/FS Phase I *Investigation Work Plan* (Phase I RIWP, Tierra 2005b) and Phase II *Remedial Investigation Work Plan* (Phase II RIWP, Tierra 2007), sediment and related investigation activities were carried out in two initial phases. On September 9, 2015, the USEPA submitted a memorandum to Tierra that described a need to characterize subunits of the Bay at an appropriate scale for RI/FS decision-making because the existing data only allowed for Bay-wide decision making (USEPA 2015). A Phase III surface sediment investigation was designed and implemented in 2016 (Phase III QAPP, Tierra 2016). Sampling was conducted in a systematic, stratified manner to collect sufficient data to characterize and statistically compare surface sediment data in the various geomorphic zones and defined subunits of the Bay, and a number of previous Phase I/II locations were resampled to provide data for recent (i.e., previous decade) trend analyses. This program was also designed/intended to provide a baseline surface sediment sampling grid for the NBSA to utilize for future sampling events to conduct long-term trend analyses.

In addition to the RI investigations, a number of focused investigations were conducted to provide the necessary data and information to conduct a BHHRA and BERA for the NBSA. These included a reconnaissance survey (Tierra 2013c), sediment quality triad (SQT) and porewater sampling and analysis (Tierra 2015a), crab and clam sampling and analysis (Tierra 2014a), and fish sampling and analysis (Tierra 2014b).

All work for this RI was carried out in accordance with USEPA-approved sampling plans. Section 2 of this RI Report describes the various RI phases and investigations, and the complete dataset for the NBSA is presented in Section 4. The BHHRA and BERA are are summarized in Section 6, and the full reports are attached as Appendix X.

1.4 Report Organization

Together with this introductory section, this RI Report is organized as follows:

- Section 2 – Newark Bay Study Area Investigations
- Section 3 – Newark Bay Study Area Physical Characteristics
- Section 4 – Nature and Extent of Contamination
- Section 5 – Newark Bay Study Area Fate and Transport
- Section 6 – Risk Assessment
- Section 7 – Updated Conceptual Site Model
- Section 8 – Summary and Conclusions
- Section 9 – References

2 NEWARK BAY STUDY AREA INVESTIGATIONS

The RI activities in the NBSA involved sampling to characterize the nature and extent of contamination in the NBSA, support BHHRA and BERA activities, and complete source identification. RI sampling activities were conducted according to the approach laid out in USEPA-approved QAPP and work plans for each phase of work.

The Bay RI field and sampling activities described in Section 2.1, and summarized in Table 2-1, include Phase I, II, III, and risk assessment investigations. Data collected by others outside of the RI process, but located within the NBSA, is referred to as secondary data and is discussed in Section 2.2. Modeling activities to support the RI/FS process are discussed briefly in Section 2.3.

2.1 Investigations Conducted under the Remedial Investigation/Feasibility Study Program

2.1.1 Phase I Site Investigation

The Phase I site investigation, which was implemented in 2005, was the initial effort to characterize the nature and extent of contamination in the NBSA. It consisted of sediment core collection and analyses, biologically active zone (BAZ) investigations, bathymetry surveys, and an investigation of sources of pollutants and contaminants. The Phase I investigation was designed to address the RI goals by meeting the specific objectives listed in Table 2-2.

2.1.1.1 Phase I Sediment Sampling

The Phase I sediment sampling included collection of sediment cores from seven geomorphic areas (Figure 2-1) of the NBSA for chemical and radiological analyses. Sediment samples were analyzed for the parameter groups listed in Table 2-3. Sediment cores were collected using vibracoring techniques by Ocean Surveys, Inc. (OSI) from 69 locations between October 30 and December 12, 2005. At 51 of the 69 coring locations, two cores (referred to as primary and secondary) were collected to provide adequate sample volume for both chemistry and radiochemistry analyses. At the remaining 18 locations, only a primary core was collected for chemical analyses. Sediment core collection depths ranged from 0.5 to 11 feet below sediment surface (bss), with 0.5 to 2-foot sample intervals. In addition, one Ponar dredge grab sample was collected at each of the 69 locations for beryllium-7 analysis to determine whether recent sedimentation had occurred at the core location. Grain size analyses were performed on a subset of samples from each core to screen for general patterns in sediment texture (Tierra 2008a, 2014c). The locations of sediment samples collected during Phase I sampling is shown on Figure 2-1.

Core radiochemistry data were collected and evaluated during Phase I primarily to establish the approximate depth of the 1940 horizon. Characterizing NBSA sediments to a depth corresponding to the year 1940 is a requirement of the NBSA AOC (USEPA 2004) and was originally negotiated as part of the 1994 Passaic River Study Area (PRSA) AOC to confirm that the vertical extent of contamination in the Passaic River would be captured during the PRSA sediment investigation. Radiochemistry analyses included lead-210, beryllium-7, and cesium-137 (Tierra 2005b, 2011).

The Phase I investigation characterized the spatial distribution and concentrations of contaminants in sediments. Details of the field and analytical activities for the Phase I site investigation are provided in the *Investigation Work Plan (IWP)/Sampling and Analysis Plan (SAP)/Site Management Plan (SMP)/Quality Assurance Project Plan (QAPP)* (Tierra 2005b), and the *Field and Data Report* (FDR; Tierra 2008a). Field, laboratory, data quality assurance/quality control (QA/QC) procedures, and data validation were also implemented, as specified in the QAPP (Tierra 2005b).

2.1.1.2 Evaluation of the Biologically Active Zone

The purpose of the evaluation of the BAZ was to evaluate the level of bioturbation that plays a key role in distributing pollutants within the BAZ (Tierra 2008b). The sampling event involved installation of a sediment profile camera system at each location followed by collection of three grab samples, for a total of 14 locations. For this evaluation, the BAZ was divided into two zones – an upper zone extending from the sediment surface to the average depth of active burrow structures and a lower zone extending from the average depth of active burrows to the maximum depth of active feeding voids. The results of the BAZ evaluation were summarized in the *Estimation of the Biologically Active Zone, Newark Bay New Jersey* (Diaz and Arcadis U.S., Inc. [Arcadis] 2008) report.

2.1.1.3 2005 Bathymetric Survey

As part of the Phase I site investigation, a single-beam bathymetric survey was completed in 2005. The survey was performed by OSI between October 7 and October 20, 2005. The primary purpose of the Phase I bathymetry survey was to verify geomorphic areas and to ensure that transitional slope cores were collected at approximately mid-slope. The survey results led to several adjustments of the Phase I geomorphic regions, which are described in detail in the Phase II RIWP (Tierra 2007). The findings did not result in changes to proposed coring locations.

During the survey, simultaneous dual-frequency (200 kilohertz [kHz] and 24 kHz) soundings were obtained along a survey line plan composed of approximately 180 transects. These transects were generally spaced at 0.25-mile intervals oriented perpendicular to the Bay, with more closely spaced, shorter tracklines near shoreline structures, bridge crossings, and sharp breaks in slope (e.g., navigational channel). In anticipation of USACE-conducted bathymetric surveys to support ongoing navigation channel dredging in the southern region of the Bay (conducted as part of the 50-foot NY/NJ HDP), the survey transects crossing the southern navigation channel were eliminated from the original bathymetry survey plan. OSI provided bathymetry data referenced to North American Vertical Datum of 1988 and horizontal coordinates referenced to the New Jersey State Plane Coordinate System, North American Datum of 1983. The results of the bathymetry survey are included in the Phase II RIWP (Tierra 2007).

2.1.1.4 Investigation of Sources of Pollutants and Contaminants

A source investigation program compiled and developed information on potential sources and associated contaminants impacting the NBSA, including three major tributaries (Hackensack River, Kill Van Kull, and Arthur Kill) and smaller direct and indirect tributaries. The investigation program was organized into four components:

- Identification of potential contaminant sources to the NBSA from review of publicly available records
- Investigation of publicly owned treatment works (POTWs), combined sewer outfalls (CSOs), and storm sewer outfalls (SSOs) in the NBSA
- Investigation of waterfront-located sources in the NBSA
- Investigation of tributary sources in the NBSA (Tierra 2006)

Publicly available documentation regarding sources impacting the NBSA was reviewed, and results of this investigation are provided in the *Report on Investigation of Sources of Pollutants and Contaminants* (Tierra 2006).

2.1.2 Phase II Site Investigation

The Phase II site investigation, which was conducted in 2007 as an extension of the Phase I site investigation, was implemented pursuant to the Phase II RIWP (Tierra 2007). The Phase II RIWP, based on preliminary review of the Phase I analytical data, determined that all but one of the nine established Phase I data quality objectives were met. Specifically, the data suggested that certain Phase I sediment cores did not extend sufficiently to capture the depth of the 1940 sediment horizon as called for in the NBSA AOC. Consequently, Tierra proposed to return to those locations during Phase II in an attempt to penetrate to the 1940 horizon depth (Tierra 2007, 2014c). In addition, Tierra targeted other potentially high historical deposition rate areas shown in the USACE's report *Geomorphological/ Geophysical Characterization of the Nature and Dynamics of Sedimentation and Sediment Transport in Newark Bay Focusing on the Effects Related to Continued and Future Federal Navigation Channel Deepening and Maintenance* (USACE 2006a). Investigations into these isolated areas provided information pertaining to the Bay's overall contaminant loading history (Tierra 2007).

The Phase II investigation was designed to address RI goals 1 and 3 by meeting the specific objectives listed in Table 2-2.

2.1.2.1 Phase II Sediment Sampling

The Phase II sediment sampling included collection of sediment cores from 50 locations within the NBSA and its tributaries. Twenty-nine of these were deep cores (down to approximately 30 feet bss) collected for both chemical and radiochemical parameters, and 21 were shallow cores (down to 0.5 foot bss) collected for chemical parameters only. Target depths for the 29 deep cores were estimated to capture the depth of the 1940 horizon based on results of the Phase I analyses and the analysis of the USACE (2006a). Grain size was measured in five segments in each of the 29 deep cores: one from the top of the core, three from the middle of the core, and one from the bottom of the core. One grain size sample was collected from each of the 21 shallow cores. Additionally, sediment grab samples were collected adjacent to each of the 50 Phase II sediment core locations; the top 1 inch of sediment was retained for beryllium-7 analysis to determine whether recent sedimentation had occurred at the core location (Tierra 2008a, 2014c). The *Phase I and Phase II Data Evaluation and Analysis Report* (DEAR) provides additional sediment sampling details (Tierra 2014c).

The locations of sediment samples collected during Phase II sampling are shown on Figure 2-1. Twelve of the Phase II cores were co-located with Phase I cores, and 24 cores were completed in potential high net depositional areas.

Chemical analyses are provided in Table 2-3. Geotechnical parameters included grain size and specific gravity (Tierra 2007). The FDR provides tables that summarize the physical, chemical, and radiochemical samples collected at each Phase II location (Tierra 2008a).

Details of the field and analytical activities for the Phase II site investigation are provided in the Phase II RIWP (Tierra 2007) and the FDR (Tierra 2008a). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the QAPP elements of the Phase II RIWP (Tierra 2007).

2.1.3 Phase III and Risk Assessment Site Investigations

A Phase III site investigation, and several additional sampling programs to collect the data necessary to conduct the BHHRA and BERA, were conducted between 2012 and 2016. Together with the Phase I and II investigations, these investigations provide the necessary data to complete this RI, as discussed in the *Conceptual Site Model* (CSM; GSH 2018). These investigations are discussed in sequence of performance below.

2.1.3.1 2012/2013 Multi-Beam and Single-Beam Survey

OSI conducted a bathymetry survey between December 4, 2012 and February 19, 2013 in the main body of Newark Bay (including Port Newark Channel, Elizabeth Channel, and South Elizabeth Channel), southern portions of the Hackensack and Passaic Rivers, and the confluence of the Bay, the Arthur Kill, and Kill van Kull (including South of Shooters Island Reach and a portion of the Elizabeth River). The purposes of the 2012/2013 survey were to:

- Generate a current dataset to represent sediment bed elevations within the NBSA and mouth of the Passaic River to support hydrodynamic and sediment transport modeling
- Develop empirical data to support the NBSA CSM (Tierra 2013; Revision 1, GSH 2018)
- Characterize changes in bathymetry since the 2005 survey (Tierra 2013b)

Multi-beam technology was used for surveying deeper areas, while single-beam technology was used in shallower areas. In general, multi-beam data acquisition was accomplished within the survey area up to elevation -8 feet relative to National Geodetic Vertical Datum of 1929 (NGVD29). Single-beam data were acquired inshore of the -8-foot NGVD29 elevation contour up to the shallowest practical depth, with a target water depth of 3 feet at the time of the survey. Planned multi-beam survey lines were constructed in advance of the field program and were supplemented where needed based on actual depth/tide conditions encountered. Planned lines were generally oriented parallel to the major contours of the water body (bay, river, or kill) and spaced at an interval that would result in overlap of the outer limits of the multi-beam echosounder swath equal to at least 10% of the width of the swath. In practice, the swath overlap percentage varied widely based on the actual water depth, undulating bottom depths, slope, sea conditions, tide, etc. The multi-beam echosounder was operated in geographic "blocks" that were generally less than approximately 3,500 feet in length. The single-beam trackline plan consisted of nominally 100-foot spaced lines oriented roughly perpendicular to the shoreline or major contours in each

area (Tierra 2013b). The results of the 2012/2013 bathymetry survey are shown on figures included in the *Multi-beam and Single-beam Bathymetric Survey Final Report* (Tierra 2013b). The bathymetric survey was performed in accordance with the QAPP (Tierra 2012b).

2.1.3.2 Shoreline/Habitat Survey

The Shoreline/Habitat Reconnaissance Survey for the NBSA was conducted in 2013 as part of the BHHRA and BERA activities for the RI/FS. Tasks for this work were completed as per the *Reconnaissance Survey Work Plan* (Tierra 2013c), with some minor deviations. The survey was completed by boat and video, and still cameras were used to record various shoreline/habitat data, including:

- Shoreline/habitat characterization information
- Characterization of human use of shoreline areas
- Identification of sampling areas and evaluation of sampling approaches
- Bird nest and mammal surveys.

Survey findings, including a photograph log and a shoreline characterization video, are provided in the *Newark Bay Study Reconnaissance Survey Report* (Tierra 2015b). Figure 2-2 shows the shoreline habitat characterization, and Figure 2-3 shows the shoreline human use characterization.

2.1.3.3 Crab and Clam Sampling Program

As part of the BHHRA and BERA investigations, blue crab (*Callinectes sapidus*), softshell clam (*Mya arenaria*), and co-located surface sediment sampling were conducted in late summer/early fall 2014. This work was performed in accordance with the *Crab and Clam Sampling and Analysis Quality Assurance Project Plan* (Tierra 2014a). These data were collected to support the objectives of the NBSA BHHRA and BERA listed in Table 2-2.

Crab tissue samples collected as part of this program included hepatopancreas, edible muscle, and carcass samples. A total of 37 samples of each crab tissue type were collected, and 18 clam samples were collected. Tissue samples were analyzed for the parameter groups listed in Table 2-3. Additionally, 18 co-located surface sediment samples were collected from the softshell clam locations in intertidal areas. Sediment samples were analyzed for the parameter groups listed in Table 2-3. Crab and clam and surface sediment sample locations are shown on Figure 2-4.

Details of the field program are provided in the *Newark Bay Study Area Environmental Sample Collection Report* (Normandeau 2017). Results for the crab and clam sampling program are provided in the *Crab and Clam Data Report* (GSH 2017a). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the QAPP (Tierra 2014a).

2.1.3.4 Fish Sampling Program

A fish sampling program was conducted as part of the BHHRA and BERA activities, which included a community survey, fish tissue sampling, and a fish health study. These activities were conducted in

accordance with the *Fish Sampling and Analysis Quality Assurance Project Plan* (Tierra 2014b) to support the BHHRA and BERA objectives listed in Table 2-2.

A total of 44 fish species were collected over sampling events conducted in three phases (fall 2014, spring/summer 2015, and spring 2016) (Normandeau 2017). This combined fish sampling program resulted in a total of 12,513 specimens. The fish collection effort in 2014 included a total of 31 fish species represented by 6,452 individuals. For all sampling efforts, various combinations of eel pots, minnow traps, seine hauls, trawls, and gillnet sets were used. Species counts were collected to supplement existing NBSA fish community data. The 2015 sampling effort yielded a total of 24 fish species represented by 2,243 individuals. The targeted species in this event were: American eel, flounder/hake, white perch, striped bass, and bluefish. The sampling effort in 2016 resulted in a total of 25 fish species represented by 3,821 individuals, although white perch was the only targeted species for 2016.

Fish tissue samples were analyzed for the parameter groups shown in Table 2-3. Information regarding fish species collected and analytical results are reported in the *Fish Data Report* (Tierra 2017). Fish were collected from various locations along the subtidal flats, transitional slopes, and navigational channel throughout each of the three zones (north, south, central) to provide spatial coverage across the NBSA. Sample locations for 2014, 2015, and 2016 are shown on Figures 2-5, 2-6, and 2-7, respectively.

Additional data were also collected to provide qualitative information about the health of fish in the NBSA. During fish tissue sampling, non-forage fish were externally examined, and any gross physical abnormalities, lesions, or anomalies were documented. A subset of individual forage fish collected were externally examined. Additionally, a representative sample of individual non-forage fish were subjected to internal pathological examination in 2014 and 2015. The fish pathology evaluations included overall morphology, gonad condition, presence of lesions, gonadosomatic index, and internal physical conditions/abnormalities.

Information regarding the fish health results, as well as details of the analytical program, are reported in the *Fish Data Report* (Tierra 2017). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the QAPP (Tierra 2014b).

2.1.3.5 Sediment Quality Triad and Porewater Sampling Program

An SQT and porewater sampling program was conducted in September 2015. The SQT and porewater program was conducted in support of the BHHRA and BERA and in accordance with the *Sediment Quality Triad and Porewater Sampling and Analysis Quality Assurance Project Plan* (Tierra 2015a). This program was implemented to meet the objectives identified in Table 2-2.

Sediment grab samples were collected from 43 locations over 13 days. The SQT analyses (i.e., sediment chemistry, toxicity testing, and benthic invertebrate community analysis) and porewater chemistry analyses were conducted at 30 of these locations. Samples from the remaining 13 locations were evaluated only for sediment chemistry for the purposes of quantifying contaminant levels in shoreline/nearshore areas where potential human exposure may occur (Figure 2-8). Sediment samples were analyzed for the parameter groups listed in Table 2-3.

An ex-situ laboratory porewater passive sampling program was conducted on field-collected sediments by researchers at the University of Maryland Baltimore County, in coordination with Arcadis and Tierra.

Passive samplers for select organic compounds included polyoxymethylene for PCDDs/PCDFs and polyethylene for PCB congeners, pesticides, and SVOCs via select ion monitoring. Strips of these samplers were deployed in sediments to extract compounds from the porewater fraction of the sediment. The organic compounds were then extracted from the samplers and the resulting data were used to estimate concentrations of these compounds in the porewater. Large-volume (0.5 liter) diffusion bags were used to capture porewater for direct analysis of metals and other inorganics (i.e., mercury, methylmercury, dissolved organic carbon, ammonia, and total sulfide). A total of 30 porewater samples were analyzed using these methods.

Sediment samples collected from the 30 SQT locations were subject to two toxicity tests using the amphipod *Leptocheirus plumulosus*. These included a short-term 10-day exposure for survival and a longer-term 28-day exposure for survival, growth, and reproduction (GSH 2017d).

Bioaccumulation tests (laboratory exposures of polychaete worms using field-collected sediments) were conducted at a subset of eight locations. Polychaete tissue samples were analyzed for the parameter groups listed in Table 2-3.

Details of the field program are provided in the *Sediment Quality Triad and Porewater Field Report* (GSH 2017e). Results for the sediment quality triad and porewater sampling program are provided in the *Sediment Quality Triad and Porewater Data Report* (GSH 2017d). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the *Sediment Quality Triad and Porewater Sampling and Analysis Quality Assurance Project Plan* (Tierra 2015a).

2.1.3.6 Surface Sediment Sampling Program

The Phase III sediment investigation program was conducted in fall 2016, pursuant to the *Newark Bay Study Area Phase III Sediment Investigation Quality Assurance Project Plan Amendment* (Phase III QAPP; Tierra 2016). This program was implemented to meet the objectives identified in Table 2-2.

Sediment samples were collected using vibracore and PONAR grab samplers. A total of 173 discrete vibracore surface sediment samples and 47 grab samples were collected in the NBSA under this program (Figure 2-9). The vibracore samples and 10 of the grab samples were analyzed as discrete samples, while the remaining grab samples were combined into 10 composite samples. Sediment samples were analyzed for the parameter groups listed in Table 2-3.

Details of the field program and analytical results are provided in the *Phase III Sediment Investigation Field Report* (GSH 2017b) and in the CSM (GSH 2018). Field, laboratory, data QA/QC procedures, and data validation were also implemented, as specified in the Phase III QAPP (Tierra 2016).

2.1.3.7 Combined Sewer Overflow and Stormwater Outfall Characterization

Information data gaps from the source investigation conducted by Tierra (2006) were addressed by subsequent work carried out in accordance with the *Combined Sewer Overflow and Stormwater Outfall Characterization – Phase I: Reconnaissance Work Plan – Information Gathering* (GSH 2017c). The objective of this reconnaissance study was to develop an inventory of CSO outfalls, SWOs, emergency relief points, POTW outfalls, and outfall points for permitted industrial facilities that discharge to the NBSA, including location, history, operational status, and construction details, when available. Specifically, the following information was sought from public agencies or public databases to address

data gaps remaining after the publication of the *Report on Investigation of Sources of Pollutants and Contaminants* (Tierra 2006):

- The locations of SWOs in Newark, Kearny (southern section), Jersey City, Bayonne, and Elizabeth, NJ, and Staten Island (Port Richmond), NY
- A listing of the names of significant industrial user dischargers located within the NBSA that were cited for violations of applicable permit conditions and a description of related permit violations
- More robust technical information related to the sewer systems, including reports and mapping to help identify additional mechanisms for sources of contaminants to enter into the NBSA from the POTWs identified above (GSH 2017c).

The results of the reconnaissance study are included in the *Combined Sewer Overflow and Stormwater Outfall Characterization – Phase I: Reconnaissance Report – Information Gathering* (GSH 2017f).

2.2 Secondary Data

The NBSA has been studied by numerous agencies, institutions, and industry consultants over the last several decades. These studies are reported in several different publications, including government reports, university reports and theses, and scientific journal articles. A comprehensive search and summary of available data for the NBSA was undertaken by Tierra during development of the RIWP. The historical data collected up until that time are detailed in the *Newark Bay Study Area RIWP, Sediment Sampling and Source Identification Program, Volume 1a of 3, Inventory and Overview Report of Historical Data* (Tierra 2004).

Additional secondary data were identified in cooperation with the USEPA during development of the DEAR. At the time, a process was developed to classify secondary data for usability in the characterization of the NBSA. That process was detailed in the memorandum entitled *Updating the Inventory Report Bibliography Database (Tierra 2004) and Performing a Secondary Data Evaluation for the Newark Bay Study Area Remedial Investigation* (Tierra 2012a) and further described in Section 2.2.1.

During the preparation of the *Final Newark Bay Study Area Problem Formulation* (Tierra 2013a), a comprehensive review of secondary biological data in the NBSA was conducted and summarized. The purpose of the review was to provide the information necessary to develop ecological sampling programs for the NBSA. These data are summarized in Sections 2.2.3, 2.2.4, and 2.2.6.

The characterization of current conditions in the NBSA for this RI Report relies solely on the data collected under the RI/FS program described in Section 2.1. Secondary data will be used to provide historical perspectives and comparisons only. The following section describes historical secondary data within the NBSA, summarized in Table 2-4, and its usability for this RI.

2.2.1 Sediment

During preparation of the DEAR (Tierra 2014c), a search was conducted to identify appropriate secondary sediment data that could potentially supplement the Phase I and Phase II characterization of the NBSA. The data evaluation presented in the DEAR included data collected within the NBSA, as well within adjacent tributaries extending 2 miles from the boundaries of the NBSA. The search focused on

data collected from Year 2000 onward (some older data were evaluated), a timeframe considered comparable to that of the combined Phase I/Phase II dataset that comprised the whole RI dataset at that time. Secondary data were reviewed for applicability to the project quality objectives of the Phase I and Phase II sediment investigations and evaluated for data quality comparability to the Phase I/Phase II dataset using an evaluation process developed with the USEPA (Tierra 2014c) to assign one of three usability levels:

- Level 1 (Qualitative): Datasets with Level 1 usability were collected without documented work plans and/or a QAPP or other project planning. Such data could be utilized in a qualitative manner (i.e., referenced or cited) but not included in quantitative analyses of the NBSA.
- Level 2 (Semi-Quantitative): Datasets with Level 2 usability were those that were collected under work plans, a QAPP, or other project planning, but that lacked post-collection quality activities (e.g., comparable validation procedures to the Phase I/Phase II dataset). Level 2 data could be summarized statistically and displayed on figures, but not combined with the RI data in quantitative analyses of the NBSA.
- Level 3 (Quantitative): Datasets with Level 3 usability had undergone similar QA/QC procedures consistent with the Phase I/Phase II dataset, including work plans, a QAPP, or other project planning, as well as post-collection validation. These Level 3 data, with comparable quality procedures, could be used in the same manner as Level 2 data. In addition, they could be combined with the RI data in quantitative analyses of the NBSA, where appropriate.

Most of the secondary sediment data evaluated for the DEAR were collected from locations outside the boundary of the NBSA and were within the adjacent tributaries. In addition, the age of much of the secondary sediment data make it useful only for historical context and not current characterization of the NBSA. Current characterization of NBSA sediment for this RI relies solely on the sediment data collected under the RI/FS program described in Section 2.1. The Level 2 and 3 secondary sediment datasets that were considered for historical perspective are described below.

2.2.1.1 Level 2 Secondary Sediment Data

1998 to 2001 Contaminant Assessment and Reduction Program (CARP): In 1998, the New York State Department of Environmental Conservation (NYSDEC) and New Jersey Department of Environmental Protection (NJDEP) entered into an agreement with the Port Authority of NY/NJ to assess the environmental quality of NY Harbor. This assessment became part of the CARP under the Harbor Estuary Program and included environmental sampling of the water column, sediments, and biota (NYSDEC 2003).

The CARP sediment data were collected in two parts, the Harbor Ambient Sediment Sampling Project (HRA) and the Harbor Sediment Trackdown Sampling Project (HRT). In 1999, as part of the HRA, 18 locations across the NY/NJ Harbor were sampled for surficial sediments to characterize sediment quality conditions for the harbor modeling work. Between 2000 and 2001, as part of the HRT, additional sediment sampling was conducted to fill data gaps and provide additional information about areas of interest; this sampling included 42 sediment cores and 91 surficial sediment samples.

These data were given a Level 2 usability. The CARP data underwent some quality procedures, which included a procedure for validation. However, this validation procedure resulted in classifications that did

not provide the user with a clear understanding on the specific manner to utilize the reported result. Without making interpretations on the validation classifications (such as "use with caution"), the data could not be considered of comparable quality to the RI data with respect to validation.

Sediment sampling under these programs included only four locations within the NBSA. For this reason, and the age of these samples, these CARP data are of limited use for this RI.

2008 USACE Stratified Sampling Project: The USACE collected 22 sediment cores to test the vertically stratified sediment in specific areas of the NY/NJ Harbor Estuary as part of the ongoing HDP (USACE 2010a). The sediment cores were analyzed for 2,3,7,8-trichlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), PCB congeners 77 and 169, benzo(a)pyrene, lead, mercury, arsenic, cadmium, copper, high-molecular weight and low-molecular weight PAHs, TEPH, TOC, dichlorodiphenyltrichloroethane, Total PAHs, Total PCBs, grain size, and related geophysical parameters (USACE 2010a).

The data generated as part of this project were characterized as Level 2 usability. These data did have a sampling and analysis plan, but there was no indication of data validation procedures.

Sediment sampling under this program included 22 locations within the southern geographic area of the NBSA. They are of limited use in this RI due to the focused (biased) location of the samples, focused objectives of the program, and limited analyte list.

2.2.1.2 Level 3 Secondary Sediment Data

1999 to 2006 Honeywell Sediment Investigations: Honeywell performed a series of sediment investigations between 1999 and 2006 and issued multiple reports about these investigations (Parsons and ENVIRON 2004; ENVIRON 2005, 2006). The dataset from these investigations is from a focused sediment study area along the Lower Hackensack River and the northeastern shore of the NBSA to delineate the horizontal and vertical extent of total chromium in sediment in the Lower Hackensack River near the site and to generate the information necessary to select a sediment remedy.

Between 2000 and 2006, more than 200 sediment cores and grab samples, including cores collected for radiochemical analyses, were collected as part of this program. More than 1,100 discrete sediment samples (including surface samples) were also collected as part of this program.

Based on the quality procedures that were planned and followed, as well as the validation of the data following laboratory analyses, the data associated with these Honeywell sediment investigations were characterized as Level 3 usability.

Sediment sampling under this program included 150 locations within the NBSA, most of which were collected adjacent to the site (i.e., Area 7). Many of these samples were only analyzed for chromium. Subsequent to this sampling, a Removal Action was conducted near the Honeywell site, which would have disturbed many of the original sampling locations. Due to the age and limited extent of these data, including the fact that many of the results are obsolete post-remediation, they are of limited use for this RI.

1998 – 2003 USEPA Regional Environmental Monitoring and Assessment Program (REMAP): The USEPA conducted sampling of the NY/NJ Harbor Estuary to characterize sediment quality (USEPA 2003). Twenty-eight locations were sampled in 1993-1994 and again in 1998 within the Bay sub-basin, which, under REMAP, included the LPR, Arthur Kill, and Kill van Kull. Twelve of these locations were

located within the NBSA (USEPA 2003). Each location was sampled for sediment chemistry, sediment toxicity (i.e., 10-day *Ampelisca abdita* survival), and benthic invertebrate community characterization. These sediment data were not considered in the characterization in the DEAR because they were collected prior to Year 2000. However, they were evaluated for usability and determined to be of Level 3 quality. Similar sampling was conducted in 2003 under this program. The USEPA did not provide a published report for this dataset; however, it is available online (USEPA 2016b). These data are useful for describing historical trends within the NBSA, particularly because many of the locations were re-sampled over time (Figure 2-10). All REMAP sediment sampling consisted of collecting the top 2 centimeters (cm) of sediment for evaluation.

2013 Post-Hurricane Sandy Sediment Quality Sampling: With multi-agency coordination, sediment quality sampling was conducted in 2013 in coastal areas of NY and NJ that were inundated during flooding that occurred in October 2012 during Hurricane Sandy (USGS 2015). Sediment samples from the top 2 cm were collected from 23 locations within the NBSA and were analyzed for multiple chemicals, including 2,3,7,8-TCDD, which are the only available analytical results made available to the public to date. Nine of these locations were co-located with 1998 REMAP locations (USEPA 2003) (Figure 2-10), making these data useful for describing historical trends within the NBSA.

2.2.1.3 Summary of Secondary Sediment Data

Available Level 2 secondary sediment data are of limited use for this RI. Level 3 secondary sediment data collected under the 1999 to 2006 Honeywell sediment investigations are of limited use for this RI. Level 3 REMAP and post-Hurricane Sandy sediment data are used to evaluate historical trends within the NBSA; sample data locations from these programs are depicted on Figure 2-10.

2.2.2 Surface Water

A comprehensive surface water sampling program was conducted by the CPG within the LPR and the NBSA (2011 to 2013) as part of the fate and transport modeling work being conducted by the CPG for the LPRSA and NBSA. These surface water data have been deemed sufficient by the USEPA for use in conducting the RI, BHHRA, and BERA for the NBSA (Arcadis 2015).

Chemical and physical parameters measured in surface water included the following: total and dissolved metals, butyltins, PAHs, alkylated PAHs, SVOCs, PCB congeners, PCDDs/PCDFs, organochlorine pesticides, VOCs, cyanide, dissolved organic compounds, particulate organic carbon, TOC, total dissolved solids, chlorophyll-a, and water quality parameters (Windward 2017). In discussion with the USEPA, it was agreed that the data from this program were suitable to characterize the nature and extent of contaminants in surface water in the NBSA.

The sampling program included six locations located within the NBSA (Figure 2-11), which were sampled during the events listed below.

Five routine chemical water column monitoring events were conducted in 2011 and 2012 under normal flow conditions (i.e., 400 to 3,000 cubic feet per second [cfs] at Dundee Dam):

- Event 1 was conducted from August 15 to 17, 2011, during average tide (median flow at Dundee Dam was 2,650 cfs)

- Event 2 was conducted from February 20 to 21, 2012, during spring tide (median flow at Dundee Dam was 699 cfs)
- Event 3 was conducted from March 26 to 27, 2012, during neap tide (median flow at Dundee Dam was 392 cfs)
- Event 4 was conducted from June 4 to 5, 2012, during spring tide (median flow at Dundee Dam was 1,389 cfs)
- Event 5 was conducted from December 10 to 11, 2012, during average tide (median flow at Dundee Dam was 664 cfs)

A single low-flow (i.e., less than 400 cfs at Dundee Dam) water column monitoring event was conducted in August 2012 during spring tide (median flow at Dundee Dam was 253 cfs).

Two high-flow events (i.e., greater than 3,000 cfs at Dundee Dam) were conducted in 2013:

- Event 1 was conducted from February to March 2013
- Event 2 was conducted in June 2013

At each location and event, grab samples were collected from two depths in the water column: 3 feet (0.9 meter) above the bottom and 3 feet (0.9 meter) below the surface. Samples were collected at four intervals (i.e., high water slack tide, low water slack tide, maximum ebb tide, and maximum flood tide) at each location and depth.

2.2.3 Tissue

Secondary chemistry data for fish and other biota tissue are limited for the NBSA. During the 1980s, the NJDEP captured and analyzed fish for PCBs and pesticides in edible fillet samples (NJDEP 1982, 1983, 1985). Also during the 1980s, Brown et al. (1994) and Rappe et al. (1991) collected PCDD/PCDF data from various fish and shellfish tissue in the Bay. More recently, the CARP (see description in Section 2.2.1.1) captured and analyzed tissue data from one location in the center of the Bay (NYSDEC 2004a, 2004b, 2004c, 2005, 2006) from the following species: American eel, mummichog, ribbed mussel, sevenspine bay shrimp, striped bass, and white perch. Additional data are available for polychaetes and zooplankton greater than 64 microns. All tissue data were analyzed for metals, PAHs, PCBs, pesticides, PCDDs, and PCDFs.

A study by Parsons (2003), also conducted under the CARP program, analyzed samples of double-crested cormorant eggs, blood, and feathers for various chemical parameters (metals, PAHs, pesticides, PCBs, PCDDs/PCDFs) from three islands throughout the NY/NJ Harbor Estuary to determine if concentrations of contaminants were present in the birds at levels of concern, and to determine if there was any correlation between the concentrations of the contaminants and reproductive success in the population.

Additional studies (e.g., Cooper and Buchanan 2007; Bugel 2009, 2011; Gale et al. 2000) have collected biomarker data, such as external examinations; blood smears; hematocrit; total and organ weights; histopathology; biochemical endpoints, including endocrine disruption (e.g., ethoxyresorufin-O-deethylase induction); and fluorescent activity. These data attempt to document potential changes in fish at the

molecular level; however, it is difficult to scientifically link alterations in biomarkers to particular constituents.

Secondary tissue data are used for historical perspective only and as secondary lines of evidence for risk assessment. Only data collected under the RI/FS program discussed in Section 2.1 are used to characterize chemical concentrations in biota in the NBSA.

2.2.4 Sediment Toxicity Data

More than a dozen historical laboratory studies have documented sediment toxicity within the Bay and its tributaries (Tierra 2004). Various organisms were used to measure survival and growth, including amphipods (*Ampelisca abdita* and *Rhepoxynius abronius*), polychaetes (*Armandia brevis*), mysids (*Mysidopsis bahia*), bivalves (*Mulina lateralis*), and sand dollars (*Dendraster excentricus*). In general, the studies showed that, except for *A. abdita*, the organisms were not sufficiently sensitive, from either a growth or survival aspect, to evaluate differences in toxicity of various sediments (Tierra 2013a). Therefore, only secondary data from *A. abdita* survival studies were considered for use in the BERA.

There are 10 published studies that include the results of *A. abdita* survival, the largest of which were conducted by the NOAA (1995) and USEPA (2003). Additional unpublished REMAP *A. abdita* survival data collected in 2003 by the USEPA were accessed online (USEPA 2016b). Both the REMAP and NOAA studies used a stratified random design to estimate the areal extent of toxicity. The REMAP and NOAA toxicity data are used to describe historical characterizations of toxicity in the NBSA. The description of current sediment quality with respect to toxicity rely solely on the data collected under the RI/FS program described in Section 2.1.

2.2.5 Non-Remedial Investigation Bathymetric Surveys

Bathymetry surveys have been conducted since the early 1900s by the NOAA and USACE (GSH 2018). The NY District of the USACE periodically surveys channels that are their responsibility. The main channel of the NBSA was most recently surveyed in February 2018, and the results are included in Appendix X (USACE 2018).

In addition to bathymetry surveys, NOAA has prepared nautical charts since the mid-1800s (NOAA 2018). A selection of historical NOAA nautical charts from 1917 through 2017 are presented in Appendix X (NOAA 1917, 1925, 1935, 1940, 1967, 1978, 1986, 1994, 2010, 2017).

2.2.6 Biological Community Data

Benthic community data were collected under the REMAP programs described in Section 2.2.4 (USEPA 2003; USEPA 2016b) and will be used to provide historical perspective. The characterization of current conditions of the benthic invertebrate community (BIC) will rely solely on the BIC data collected under the RI/FS program described in Section 2.1.

Since 1998, the USACE has collected fish community data from various stations within the NBSA with a 30-foot otter trawl as part of the NY/NJ HDP to establish use of the channel and non-channel areas within the harbor from year to year. These sampling data are used to describe the annual variability, seasonal movement patterns, and relative species abundance in the NBSA over the sampling period (1998-2010).

The data are reported in annual *Aquatic Biological Survey Reports* (USACE 2003, 2004b, 2005, 2006b, 2007b, 2008, 2009b, 2010b, 2011) and a *Migratory Finfish Summary Report* (USACE 2015). These data are used to help describe the fish community and to estimate residence times for the species sampled in the NBSA.

2.3 Hydrodynamic, Sediment Transport, and Modeling Studies

Numerical modeling of the LPR and the Bay system is being performed by the CPG pursuant to the AOC effective May 8, 2007 (USEPA 2007a). The work is being conducted according to the *Final Modeling Work Plan* (HydroQual, Inc. [HydroQual] 2006a) and the *Final Modeling Work Plan Addendum* (HydroQual 2006b). The modeling consists of four sub-models: hydrodynamic, sediment transport, contaminant fate and transport, and bioaccumulation. The application of these models is described further in Section 5.

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TABLES

Table 1-1
History of Dredging Activities within Newark Bay

Area	Year	New Dredge Depth (feet Mean Low Water)	Wetlands and Channel Widths
Newark Bay	1844	< 10	The bay was bordered by extensive wetlands in the western and northern areas.
Newark Bay navigation channel south, central, and north reaches	1912	16	The wetlands in the western and northern areas were mostly intact but were bisected by multiple railways.
Newark Bay navigation channel south, central, and north reaches	1916	20-21	Port Newark terminal was built over reclaimed wetlands. The width of the shipping channel in the southern bay was increased to 400 feet.
Arthur Kill	1917	25	
Newark Bay navigation channel south and middle reaches and Port Newark reaches	1923	30	
Passaic River and Newark Bay navigation channel north reach	1923	20	
Passaic River and Newark Bay navigation channel north reach	Early 1930s	30	
Hackensack River	1954	32-34	
Newark Bay navigation channel south and middle reaches and Port Elizabeth reaches	1960s to 1970s	Not applicable	Most of the remaining wetlands in the western area were reclaimed. The width of southern Newark Bay was reduced in half with the building of the Elizabeth Channel.
Newark Bay navigation channel south, central, and north reaches	1960s to 1970s	35	
Newark Bay navigation channel south reach	1966	Not applicable	Channel near Kill van Kull was widened to 700 feet.
Newark Bay navigation channel south reach	1973	Not applicable	Channel near Kill van Kull was widened to 800 feet.
Newark Bay navigation channel south reach	1980	Not applicable	Channel near Kill van Kull was widened to 1,000 feet.
Newark Bay navigation channel south, central, and north reaches	1980s	40	
Newark Bay navigation channel south, central, and north reaches	1999 to 2016	50-52	See Figure 1-3 for extent of dredging.
Kill van Kull	1999 to 2016	50-52	See Figure 1-3 for extent of dredging.
Newark Bay navigation channel south reach	1999 to 2016	Not applicable	Channel near Kill van Kull was widened to 1,700 feet.
Kill van Kull navigation channel Elizabethport reach	1999 to 2016	40-43	See Figure 1-3 for extent of dredging.

Table 1-2
General Notice Letter Recipients

Recipient of General Notice Letter	Date of Letter
Honeywell International, Inc.	8/24/2006
Prentiss, Inc.	8/24/2006
Public Service Electric & Gas	8/24/2006
Troy Chemical Corporation	8/24/2006
Amcol Realty Co.	7/13/2007
BASF Catalysts LLC	7/13/2007
Bayer Corporation	7/13/2007
Chevron Texaco Corporation	7/13/2007
Colt Corporation	7/13/2007
Columbia Terminals, Inc.	7/13/2007
E.I. duPont de Nemours and Company	7/13/2007
General Cable Industries, Inc.	7/13/2007
ISP Environmental Services, Inc.	7/13/2007
OENJ Cherokee Corporation	7/13/2007
Beazer East, Inc.	9/3/2009
Cytec Industries, Inc.	9/3/2009
Exxon Mobil Corporation	9/3/2009
Koppers Inc.	9/3/2009
Reichhold, Inc.	9/3/2009
CycleChem, Inc.	1/31/2012
IBM Corporation	1/31/2012
ICI Americas Inc.	1/31/2012

Note:
The Newark Bay Study Area operable unit is part of the Diamond Alkali Superfund Site.

Table 2-1
Summary of Remedial Investigation Sampling Programs

RI Phase	Year Conducted	Sampling Program	Number of Sampling Locations	Sampling Depth (ft bss)	Sample Type	Sample Analyses	Number of Samples	Sampling Program Details
Phase I	2005	BAZ Investigation	NA	NA	NA	NA	NA	Investigation activities confirmed 0.5-ft depth bss was sufficient for BAZ sampling.
	2005	Bathymetric Survey	NA	NA	NA	NA	NA	Used to define geomorphic areas and to assist field crews with sediment core collection.
	2005	Sediment Investigation	69	0 to 11	Sediment	Chemistry, Radiochemisty	Chemistry: 301 Radiochemistry: 547	Sampling interval: 0.5- to 2-ft. Radiochemistry analyses conducted at 51 locations at non-contiguous 2-inch sampling intervals. Be-7 analyses conducted on top 1-inch of sediment at all locations.
Phase II	2007	Sediment Investigation	50	0 to 29.5	Sediment	Chemistry, Radiochemistry	Chemistry: 385 Radiochemistry: 491	Sampling interval: 0.5- to 2-ft. Radiochemistry analyses conducted at 29 locations at non-contiguous 2-inch sampling intervals. Be-7 analyses conducted on top 1-inch of sediment at all locations.
Phase III	2012/2013	Bathymetric Survey	NA	NA	NA	NA	NA	Conducted to support hydrodynamic and sediment transport modeling for the Lower Passaic River Study Area and to support the NBSA Conceptual Site Model.
	2013	Reconnaissance Survey	NA	NA	NA	NA	NA	Conducted to provide qualitative observations of shoreline features and characteristics of the NBSA as part of the Baseline Human Health and Ecological Risk Assessments.
	2014	Crab and Clam Sampling Program	18	0 to 0.5	Sediment	Chemistry	18	Co-located clam and surface sediment collected at each location.
			18	NA	Softshell Clam Tissue	Chemistry	18	
			37	NA	Blue Crab Tissue	Chemistry	111	Hepatopancreas, edible muscle, and carcass tissue samples collected at each location.
	2014, 2015, 2016	Fish Sampling Program	NA	NA	Tissue	Chemistry	190	Target species selected to represent key trophic levels and feeding guilds. Whole body, fillet, and liver fish tissue samples collected.
	2015	SQT & Porewater Sampling Program	43	0 to 0.5	Sediment	Chemistry	43	SQT analyses, benthic invertebrate community analysis, and porewater chemistry analyses conducted at 30 stations. Bioaccumulation tests conducted at a subset of eight stations. Chemistry analyses conducted on an additional 13 locations to support the Baseline Human Health Risk Assessment.
			8	NA	Tissue	Chemistry	8	
			30	0 to 0.5	Porewater	Chemistry	30	
			30	0 to 0.5	Toxicity	NA	30	
			30	0 to 0.5	Benthic Invertebrate Community	NA	90	
	2016	Sediment Investigation	220	0 to 0.5	Sediment	Chemistry	193[1]	Sampling interval: 0- to 0.5-ft.

Notes:

1. A total of 173 discrete vibracore surface sediment samples and 47 grab samples were collected in 2016, for a total of 220 individual sampling locations. The vibracore samples and 10 of the grab samples were analyzed as discrete samples, while the remaining grab samples were combined into 10 composite samples for analysis.

Acronyms and Abbreviations:

BAZ = biologically active zone
Be-7 = beryllium-7
ft bss = feet below sediment surface
ft = feet
NA = not applicable
NBSA = Newark Bay Study Area
SQT = Sediment Quality Triad

Table 2-2
Remedial Investigation Goals and Objectives by Site Investigation Phase

	Remedial Investigation Goal 1: Nature and Extent of Sediment Contamination	Remedial Investigation Goal 2: Risk Assessment	Remedial Investigation Goal 3: Source Identification
Phase I	1.Confirm the presence and extent of individual geomorphic areas. 2.Estimate the approximate depth of the 1940 sediment horizon (1940 horizon) in each defined geomorphic area. 3.Better understand broad patterns of constituents in both the surface and subsurface sediments and attempt to identify preliminary "hot spots" through statistical analyses (e.g., Rosner's test [USEPA 2006]). 4.Confirm that the current analytical suite is appropriate for the various geomorphic areas. 5.Determine data needs for subsequent phases (Tierra 2005).	1.Preliminarily characterize (through sediment sampling) the nature of contamination within select ecologically sensitive intertidal mudflats. 2.Determine the depth of the biologically active zone within each geomorphic area of the Phase I Study Area (Tierra 2005).	1.Gather information to be used in identifying ongoing sources to Newark Bay, including identification of sampling locations for future phases of work. 2.Confirm (through sediment sampling) the impact to select areas of Newark Bay and the Hackensack River believed to be affected by historical and/or current discharges (Tierra 2005).
Phase II	1.Characterize sediments to the 1940 horizon depth in select areas found to be accreting sediments at a relatively high rate, including select Phase I locations and other areas of potential high net deposition, as identified by the USACE (2006). 2.Characterize sediments (both surface and at depth) in specific regions of Neark Bay to further the understanding of broad spatial patterns for constituents of potential concern (COPCs). 3.Seek to understand matrix heterogeneity in select regions of Newark Bay (Tierra 2014c).	-	1.Characterize surface and subsurface sediments in select areas found to be potentially impacted by upland sources (Tierra 2014c).
Phase III	1. Determine the approximate boundaries of subunits within Newark Bay that contain statistically distinct concentrations of COPCs, especially dioxin. 2. Determine the means and variances of COPC concentrations within these subunits. 3. Determine how surface sediment COPC concentrations within these subunits vary with time (Tierra 2016).	*Crab and Clam Sampling Program* 1. Evaluate whether exposure to site-related constituents of potential ecological concern (COPECs) in the Newark Bay Study Area (NBSA) poses unacceptable risks to benthic macroinvertebrates (represented by blue crab and softshell clams). 2. Evaluate whether the consumption of blue crabs from the NBSA poses unacceptable risks to humans. 3. Evaluate whether the consumption of blue crabs and softshell clams from the NBSA poses unacceptable risks to ecological wildlife receptors (i.e., birds and mammals). 4. Evaluate whether exposure to surface sediments in the Intertidal Areas of the NBSA poses unacceptable risks to ecological receptors (Tierra 2014a). *Fish Sampling Program* 1. Evaluate whether exposure to site-related COPECs in the NBSA poses unacceptable risks to fish. 2. Evaluate whether the consumption of fish from the NBSA poses unacceptable risks to human and ecological receptors (e.g., birds, mammals) (Tierra 2014b). *Sediment Quality Triad and Porewater Sampling Program* 1. Evaluate whether exposure to site-related COPECs in the NBSA poses unacceptable risks to benthic invertebrate communities. 2. Evaluate whether the consumption of benthic invertebrates (represented by a laboratory-exposed bioaccumulation test) poses unacceptable risks to fish and wildlife (ecological) receptors. 3. Evaluate whether exposure to site-related COPCs in surface sediments in the shoreline Intertidal Areas of the NBSA poses unacceptable risks to human receptors (Tierra 2015).	*Combined Sewer Overflow (CSO) and Stormwater Outfall (SWO) Characterization* 1. Develop an inventory of CSO outfalls, SWOs, emergency relief points, publicly owned treatment works outfalls, and outfall points for permitted industrial facilities that discharge to the NBSA (GSH 2017).

Table 2-2
Remedial Investigation Goals and Objectives by Site Investigation Phase

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Table 2-3
Newark Bay Study Area Remedial Investigation Analytical Summary

Parameter Group[1]	Phase I	Phase II	Phase III				
	Sediment	Sediment	Crab/Clam Sediment	SQT Sediment	Surface Sediment	Biota Tissue	Porewater
Ammonia Nitrogen	-	-	X	X	-	-	X
AVS/SEM	-	-	X	X	-	-	-
DOC	-	-	-	-	-	-	X
Grain Size	X	X	X	X	X	-	-
Herbicides	X	X	X	X	X	-	-
Hexavalent Chromium	-	-	X	X	-	-	-
Lipids	-	-	-	-	-	X	-
Metals[2]	X[3]	X[3]	X	X	X	X	X
Organotins	X	-	X	X	-	X	-
ORP	-	-	X	X	-	-	-
PAHs[4]	X	X	X	X	X	X	X
PBDEs	-	X	-	-	-	-	-
PCB Aroclors	X	X	X	X	X	X	-
PCB Congeners	X	X	X	X	X	X	X
PCDDs/PCDFs	X	X	X	X	X	X	X
PCNs	-	X	-	-	-	-	-
Percent Moisture	X	X	X	X	X	X	-
Pesticides	X[5]	X	X	X	X	X	X
pH	-	-	X	X	-	-	-
Radiochemistry	X	X	-	-	-	-	-
Semivolatiles	X	X	X	X	X	X	-
Specific Gravity	-	X	-	-	-	-	-
TEPH Alkanes	-	-	X	X	X	-	-
TOC	X	X	X	X	X	-	-
Total Cyanide	X	X	X	X	X	-	-
Total Kjeldahl Nitrogen (TKN)	-	-	X	X	-	-	-
Total Phosphorus	-	-	X	X	-	-	-
Total Sulfide	-	-	X	X	-	-	X
TPH	X	X	X	X	X	-	-
Volatiles[6]	X	X	X	X	X	-	-

Notes:
1. For specific analytical methods and target analytes in each parameter group, refer to program-specific work plans, quality assurance project plans, and data reports, as referenced in Section 2.1.
2. Includes mercury and methylmercury.
3. Phase I and Phase II sediment samples were not analyzed for methylmercury.
4. Due to analytical bias, sediment samples from the Phase III sampling programs are being re-analyzed for PAHs. The data are expected to be available in October 2018.
5. Phase I sediment samples were not analyzed for 2,4'-DDD, 2,4'-DDE, or 2,4'-DDT.
6. List of target volatiles was shortened after completion of the Phase I sampling program.

Acronyms and Abbreviations:
- = not analyzed
AVS/SEM = acid volatile sulfide/simultaneously extracted metals
DDD = dichlorodiphenyldichloroethane
DDE = dichlorodiphenyldichloroethylene
DDT = dichlorodiphenyltrichloroethane
DOC = dissolved organic carbon
ORP = oxidation reduction potential
PAHs = polycyclic aromatic hydrocarbons
PCDDs/PCDFs = polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans
PBDEs = polybrominated diphenyl ethers
PCB = polychlorinated biphenyl
PCNs = polychlorinated naphthalenes
SQT = Sediment Quality Triad
TEPH = total extractable petroleum hydrocarbons
TOC = total organic carbon
TPH = total petroleum hydrocarbon

Table 2-4
Summary of Available Secondary Data[1]

Sample Type	Program	Reference
Sediment	1993/1994 Regional Estuarine and Monitoring Program (REMAP)	USEPA 1998
	1998 Regional Estuarine and Monitoring Program (REMAP)	USEPA 2003
	1998 to 2001 Contaminant Assessment and Reduction Program (CARP)	NYSDEC 2003
	1999 to 2006 Honeywell Sediment Investigations	Parsons and ENVIRON 2004; ENVIRON 2005, 2006
	2003 Regional Estuarine and Monitoring Program (REMAP)	https://archive.epa.gov/emap/archive-emap/web/html/nynj03.html
	2005 PSE&G West End Supplemental Remedial Investigation	PSE&G 2006
	2005 USEPA High Resolution Coring Program	USEPA 2005
	2007 to 2008 USEPA High Resolution/Low Resolution Supplemental Sediment Sampling Program	USEPA 2008
	2008 CPG Low Resolution Coring Program	AECOM 2010
	2008 USACE Stratified Sampling Project	USACE 2010
	2012 CPG Low Resolution Coring Supplemental Sampling Program	AECOM 2012
	2013 Post-Hurricane Sandy Sampling Program	USGS 2015
Fish	1980s NJDEP Fish Sampling	NJDEP 1982, 1983, 1985
	1980s Brown et al. and Rappe et al.	Brown et al. (1994), Rappe et al. (1991)
	Contamination Assessment & Reduction Project (CARP)	NYSDEC 2004a, 2004b, 2004c, 2005, 2006
	Additional Studies	Cooper and Buchanan 2007; Bugel 2009, 2011; Gale et al. 2000
Blue Crab	New Jersey Routine Monitoring Program for Toxics in Fish	Horwitz et al. 2006
Birds	Contamination Assessment & Reduction Project	Parsons 2003
Surface Water	2011-2013 CPG Chemical Water Column Monitoring Programs	Available on http://ourpassaic.org/

Notes:
[1]Secondary data are those derived from studies that were not conducted as part of the NBSA AOC RI investigations.

Acronyms and Abbreviations:
AOC = Administrative Order on Consent
CPG = Cooperating Parties Group
NBSA = Newark Bay Study Area
NJDEP = New Jersey Department of Environmental Protection

Table 2-4
Summary of Available Secondary Data[1]

Acronyms and Abbreviations (cont.):
NYSDEC = New York State Department of Environmental Conservation
PSE&G = Public Service Enterprise Group
RI = Remedial Investigation
USACE = United States Army Corps of Engineers
USEPA = United States Environmental Protection Agency

References:
AECOM. 2010. Lower Passaic River Study Area, Quality Assurance Project Plan. Periodic Bathymetric Surveys. May 2010, Revision 2. Prepared for Lower Passaic River Cooperating Parties Group, Newark, NJ. Prepared by AECOM, Chelmsford, MA.

AECOM. 2012. Lower Passaic River Study Area, Quality Assurance Project Plan. Low Resolution Coring Supplemental Sampling Program. June 2012, Revision 3. Prepared for Lower Passaic River Cooperating Parties Group, Newark, NJ. Prepared by AECOM, Chelmsford, MA.

Brown R.P., K.R. Cooper, A. Cristini, C. Rappe, and P.A. Berrqvist. 1994. Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans in Mya Arenaria in the Newark/Raritan Bay Estuary. Environmental Toxicology and Chemistry, Vol. 13, No. 3, pp. 523-528.

Bugel S.M. 2009. An integrated biomarker approach for assessing exposure and effects of endocrine disruptors and other contaminants in killifish (*Fundulus heteroclitus*) from the New York-New Jersey Harbor estuary (Masters dissertation). Retrieved from ProQuest Dissertations Publishing.

Bugel S.M. 2011. Contaminant effects on vitellogenesis and oogenesis in zebrafish (*Danio rerio*), and killifish (*Fundulus heteroclitus*) from the chemically impacted Newark Bay, NJ (Doctoral dissertation). Retrieved from ProQuest Dissertations Publishing.

Cooper K.R. and G.A. Buchanan. 2007. Final Report - Integrated Biomarkers for Assessing the Exposure and Effects of Endocrine Disrupters and Other Contaminants on Marine/Estuarine Fish (Second Year Grant Number SR03-038).

ENVIRON. 2005. SA7 Offshore Sediment Investigation Report. Honeywell Study Area 7; Jersey City, New Jersey.

ENVIRON. 2006. Revised Sediment Investigation Report. Honeywell Study Area 7; Jersey City, New Jersey.

Gale, R.W., E.R. Long, T.R. Schwartz, and D.E. Tillitt. 2000. Evaluation of Planar Halogenated and Polycyclic Aromatic Hydrocarbons in Estuarine Sediments Using Ethoxyresorufin-o-Deethylase Induction of H4IIE Cells. Environmental Toxiciology Chemistry, Vol. 19, No. 5 pp. 13-48-1359.

Horwitz, R. J., P. Overbeck, J. Ashley, D. Velinsky and L. Zadoudeh. 2006. Final Report: Monitoring Program for Chemical Contaminants in Fish from the State of New Jersey. Contract SR04-073. ANS Report No. 06-04F. 77pp.

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NJDEP. 1983. PCBs in Selected Finfish Caught Within New Jersey Waters 1981-1982 (With Limited Chlordane Data). Office of Science and Research.

NJDEP. 1985. A Study of Dioxin (2,3,7,8-Tetrachlorodibenzo-p-Dioxin) Contamination in Select Finfish, Crustaceans and Sediments of New Jersey Waterways. Office of Science and Research.

NYSDEC. 2003. Contamination Assessment and Reduction Project (CARP): Water. Final Report. New York State Department of Environmental Conservation, Bureau of Water Assessment and Management, Division of Water.

NYSDEC. 2004a. Polychlorinated Biphenyls (PCBs) in Fish Fish Species from the New York-New Jersey Harbor Estuary. Division of Fish, Wildlife and Marine Resources.

Table 2-4
Summary of Available Secondary Data[1]

References (cont.):

NYSDEC. 2004b. Dioxins and Furans in Five Fish Species, Blue Crabs, Invertebrates and Zooplankton from the New York-New Jersey Harbor Estuary. Division of Fish, Wildlife and Marine Resources.

NYSDEC. 2004c. Fish Tissue Contaminant Level Data. Hudson River, New York Harbor, Long Island Sound. Divison of Fish, Wildlife and Marine Resources.

NYSDEC. 2005. Organochlorine Pesticides in Five Fish Species, Blue Crabs, Invertebrates and Zooplankton from the New York-New Jersey Harbor Division of Fish, Wildlife and Marine Resources.

NYSDEC. 2006. Polynuclear Aromatic Hydrocarbons (PAHs) in Five Fish Species, Blue Crabs, Invertebrates and Zooplankton from the New York-New Jersey Harbor Estuary. Division of Fish, Wildlife and Marine Resources.

Parsons, K.C. 2003. Chemical Residues in Cormorants from New York Harbor and Control Location. Contract No. C003858. Submitted to New York State Department of Environmental Conservation, Division of Fish Wildlife and Marine Resources.

Parsons and ENVIRON. 2004. Offshore Investigation Results Summary Report. October 2003 to January 2004 Activities. Study Area 7; Jesrey City, New Jersey.

PSE&G. 2006. Final Supplemental Remedial Investigation Report - Sediment Investigation, Former West End Gas Works, Jersey City, New Jersey.

Rappe C., P.A. Bergqvist, L.O. Kjeller, and S. Swanson. 1991. Levels of Patterns of PCDD and PCDF Contamination in Fish, Crabs, and Lobsters from Newark Bay and the New York Bight. Chemosphere. Vol. 22. Nos. 3-4. pp 239-266.

USACE. 2010. Stratified Sampling Project Summary Report and Evaluation of Data. New York District.

USEPA. 1998. Sediment quality of the NY/NJ harbor system. EPA/902/R-98/001. U.S. Environmental Protection Agency, Regional Environmental Monitoring and Assessment Program (REMAP), Edison, NJ.

USEPA. 2003. Sediment Quality of the NY/NJ Harbor System: A 5-year Revisit (1993/1994–1998). EPA/902-R-03-002. U.S. Environmental Protection Agency, Region II, Edison, NJ.

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FIGURES

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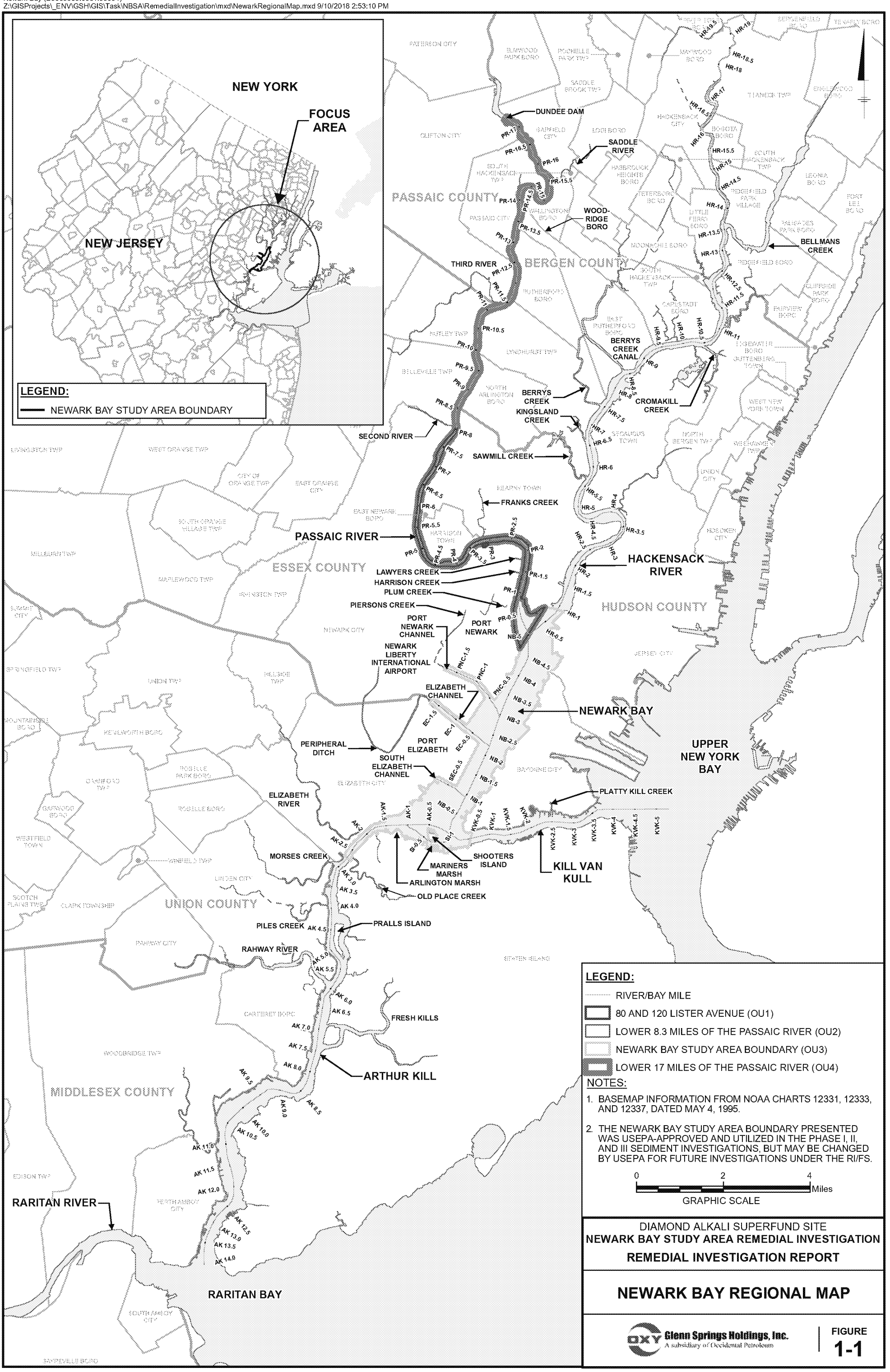

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LEGEND:

- NAVIGATION CHANNEL
- REACH BOUNDARY
- NEWARK BAY STUDY AREA BOUNDARY

NOTES:

1. AERIAL PHOTOS DATED 2015 (ESRI CLOUD IMAGERY).
2. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD 83.
3. PORT AUTHORITY OF NEW YORK AND NEW JERSEY HOWLAND HOOK MARINE TERMINAL LEASED BY AND ALSO KNOWN AS NEW YORK CONTAINER TERMINAL.
4. BASE MAP INFORMATION, REACH BOUNDARIES AND NEWARK BAY NAVIGATION CHANNEL IS FROM NOAA CHARTS 12333 AND 12337, DATED DECEMBER 2012 (UPDATED 8/13/2018) AND FEBRUARY 2013 (UPDATED 8/13/2018), RESPECTIVELY. NAVIGATION CHANNEL BOUNDARIES SHOWN ARE APPROXIMATE. CHANNEL DREDGING AND DEEPENING AS PART OF THE HARBOR DEEPENING PROJECT IS ON-GOING; CONTACT USACE TO REFERENCE THE MOST CURRENT CHANNEL BOUNDARIES.
5. THE NEWARK BAY STUDY AREA BOUNDARY PRESENTED WAS USEPA-APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS, BUT MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.

0 0.8 1.6
Miles
GRAPHIC SCALE

ROUTE 1 & 9 BRIDGE
PASSAIC RIVER
KEARNY POINT REACH
KEARNY POINT
HACKENSACK RIVER
CONRAIL BRIDGE REMNANTS
PIERSONS CREEK
LIGHT "5"
DROYERS POINT REACH
LIGHT "NB"
DROYERS POINT
TURNING BASIN
LOWER PASSAIC RIVER RESTORATION PROJECT (LPRRP) DOWNSTREAM BOUNDARY
NEWARK LIBERTY INTERNATIONAL AIRPORT
PORT NEWARK CHANNEL
PORT NEWARK INSHORE CHANNEL
PORT NEWARK INSHORE REACH
LEHIGH VALLEY LIFT BRIDGE
NORTH REACH
JERSEY CITY
ELIZABETH CHANNEL
PORT NEWARK PIERHEAD CHANNEL
NEWARK BAY BRIDGE (VINCENT R. CASCIANO I-78 MEMORIAL BRIDGE)
PORT NEWARK BRANCH REACH
PORT ELIZABETH INSHORE CHANNEL
PORT ELIZABETH BRANCH REACH
PORT NEWARK PIERHEAD REACH
MIDDLE REACH (SOUTH)
MIDDLE REACH (NORTH)
PORT NEWARK BRANCH CHANNEL
NEWARK
NEWARK BAY CDF (CELL 1S)
NEWARK BAY
PORT ELIZABETH BRANCH CHANNEL
PORT ELIZABETH MARINE TERMINAL
PERIPHERAL DITCH
PORT ELIZABETH PIERHEAD CHANNEL
SOUTH ELIZABETH CHANNEL
ELIZABETH SOUTH REACH
SOUTH REACH
ELIZABETH
BAYONNE
ELIZABETH RIVER
BAYONNE BRIDGE
NORTH OF SHOOTERS ISLAND REACH
BERGEN POINT WEST REACH
BERGEN POINT EAST REACH
ARTHUR KILL LIFT BRIDGE
SHOOTERS ISLAND
SOUTH OF SHOOTERS ISLAND REACH
PORT RICHMOND
KILL VAN KULL
ELIZABETHPORT REACH
HOWLAND HOOK MARINE TERMINAL
PORT IVORY
MARINERS HARBOR
GOETHALS BRIDGE
GULFPORT REACH
ARTHUR KILL
STATEN ISLAND
PRALLS ISLAND

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

NEWARK BAY REGIONAL FEATURES

Glenn Springs Holdings, Inc.
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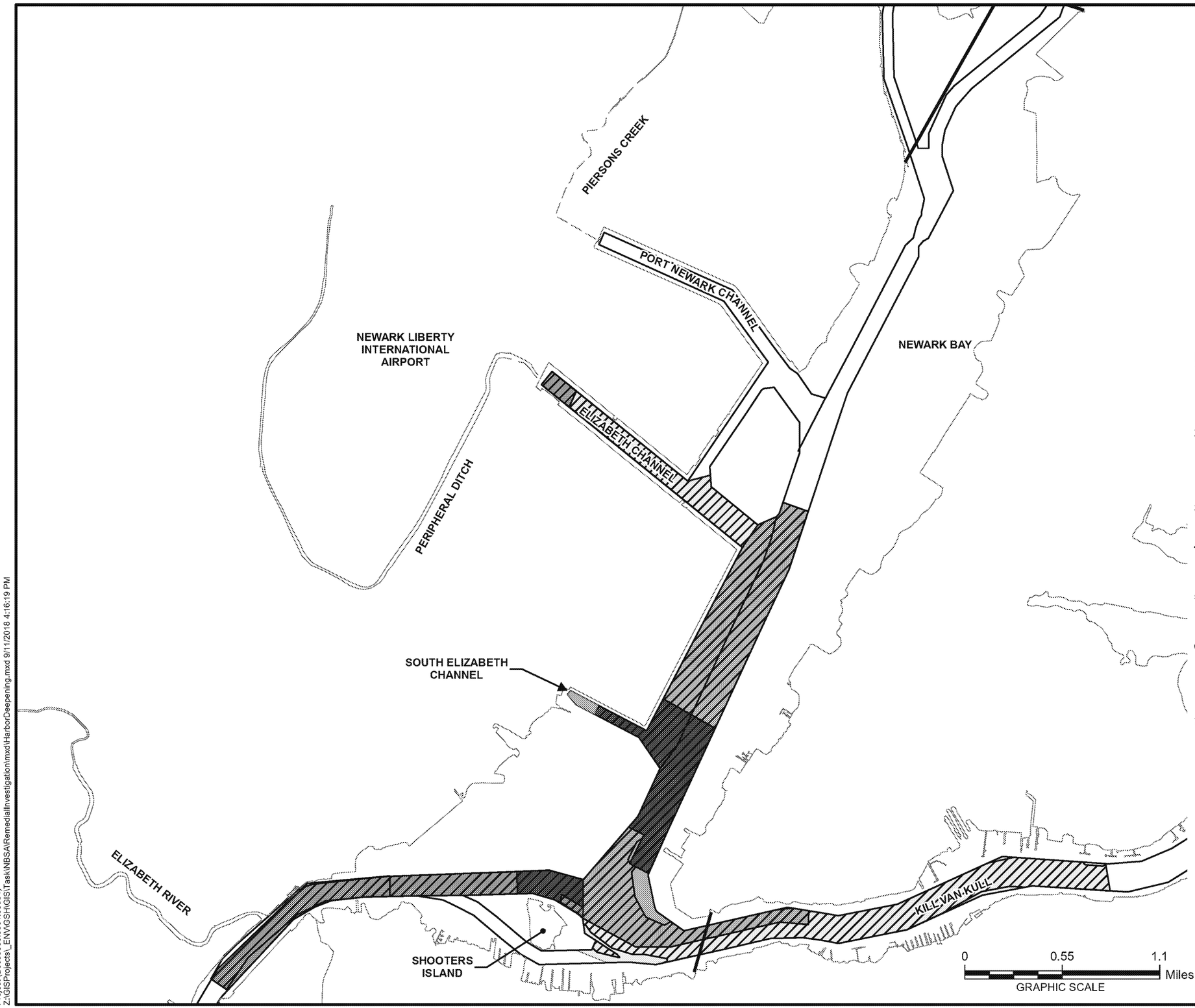
FIGURE
1-2



LEGEND:

- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY

NBSA HDP CONTRACT AREAS

- 5 - COMPLETE (2004)
- S-AK-1/S-NB-2 - COMPLETE (2012)
- S-AK-2 - COMPLETE (2013)
- S-AK-3 - COMPLETE (2016)
- S-E-1 - COMPLETE (2010)
- S-KVK-2 - COMPLETE (2007)
- S-NB-1 - COMPLETE (2011)
- DEFERRED WORK AREA
- COMPLETED CONTRACT AREAS

NOTES:

1. BASE MAP SOURCE: TOPO-METRICS, 1"=100', ORIGINAL MYLAR POSITIVES OF AERIAL PHOTOMETRICS SURVEY (1982). SECOND RIVER AND THIRD RIVER WERE DIGITIZED USING UNITED STATES GEOLOGICAL SURVEY TOPOGRAPHIC MAPS.
2. CONTRACT AREAS OBTAINED FROM A FIGURE PROVIDED BY THE U.S. ARMY CORPS OF ENGINEERS (USACE) ENTITLED "CONSOLIDATED IMPLEMENTATION OF THE NEW YORK AND NEW JERSEY HARBOR DEEPENING PROJECT (HDP)" DATED JANUARY 2004.
3. THE CONTRACT FOR S-NB-2 WAS COMBINED WITH THE CONTRACT FOR S-AK-1. THE COMBINED AREA IS CALLED S-AK-1.
4. THE CONTRACT AREA BOUNDARIES PRESENTED ON THIS FIGURE ARE BASED ON INITIAL PLANS AND MAY BE SLIGHTLY DIFFERENT FROM FINAL DESIGN BOUNDARIES.
5. ABBREVIATIONS ARE AS FOLLOWS:
   NBSA = NEWARK BAY STUDY AREA
   HDP = HARBOR DEEPENING PROJECT (50 FT)
6. DEFERRED WORK AREAS ESTIMATED FROM A 2012 PRESENTATION BY JOHN TAVOLARO (USACE) AND CONVERSATION WITH BRYCE WISEMILLER ON JUNE 6, 2012. THE DEFERRED WORK AREA AT ELIZABETH CHANNEL WAS INCLUDED AS PART OF DEEPENING WORK ASSOCIATED WITH THE S-AK-3 CONTRACT AREA.
7. BASE MAP INFORMATION, REACH BOUNDARIES AND NEWARK BAY NAVIGATION CHANNEL IS FROM NOAA CHARTS 12333 AND 12337, DATED DECEMBER 2012 (UPDATED 8/13/2018) AND FEBRUARY 2013 (UPDATED 8/13/2018), RESPECTIVELY. NAVIGATION CHANNEL BOUNDARIES SHOWN ARE APPROXIMATE. CHANNEL DREDGING AND DEEPENING AS PART OF THE HARBOR DEEPENING PROJECT IS ON-GOING; CONTACT USACE TO REFERENCE THE MOST CURRENT CHANNEL BOUNDARIES.

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REMEDIAL INVESTIGATION REPORT

NEW YORK/NEW JERSEY HARBOR DEEPENING PROJECT (50 ft)

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FIGURE 1-3

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
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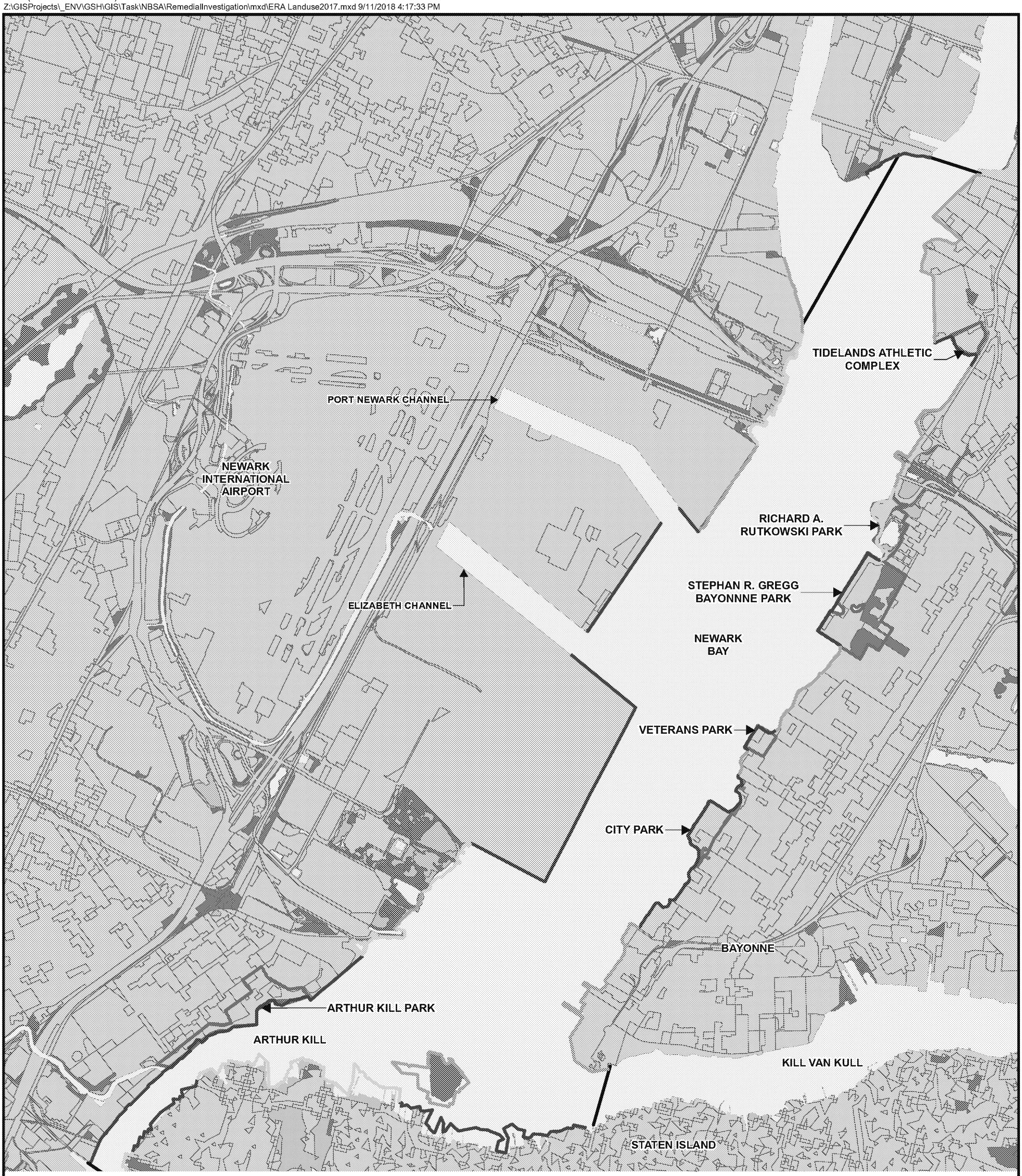
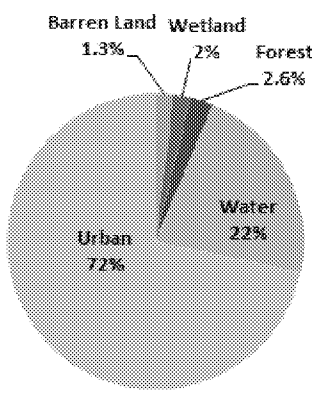


LEGEND:

- BARREN LAND
- FOREST
- URBAN
- WATER
- WETLANDS
- PARKS AND RECREATIONAL AREAS
- NEWARK BAY STUDY AREA BOUNDARY

OBSERVED SHORELINE HABITAT:

- BULKHEAD
- MIXED INTERTIDAL
- RIPRAP
- VEGETATION



Percentage of Land Cover

NOTES:

1. 2012 NEW JERSEY LAND USE DATA (UPDATED IN 2015) DOWNLOADED FROM THE NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION GEOGRAPHIC INFORMATION SYSTEM WEBSITE AT www.state.nj.us/dep/gis.
2. 2011 NEW YORK NATIONAL LAND COVER DATA DOWNLOADED FROM THE NEW YORK STATE GEOGRAPHIC INFORMATION SYSTEMS CLEARINGHOUSE AT www.nysgis.state.ny.us.
3. THE NEWARK BAY STUDY AREA BOUNDARY PRESENTED WAS USEPA-APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS, BUT MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
4. SHORELINE HABITAT OBSERVATIONS WERE MADE IN 2013 DURING THE RECONNAISSANCE SURVEY (TIERRA 2015).
5. REFERENCES:
A. TIERRA. 2015. NEWARK BAY STUDY AREA RECONNAISSANCE SURVEY REPORT. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. APRIL.

0 3,000 6,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

LAND USE/ECOLOGICAL HABITATS

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FIGURE
1-4

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City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Newark Bay (B0009989.0061.00004)
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LEGEND:

- PHASE I SEDIMENT CORE LOCATION
- PHASE II SEDIMENT CORE LOCATION
- CO-LOCATED CORE LOCATION
- ABANDONED CORE LOCATION; NO SAMPLES COLLECTED
- PHASE I BAZ INVESTIGATION LOCATION
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- POTENTIAL HIGH NET DEPOSITION AREA

GEOMORPHIC AREAS:

- HISTORICALLY DISTURBED SUBTIDAL FLATS
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREA
- NAVIGATION CHANNEL
- PORT CHANNEL
- SUBTIDAL FLATS
- TRANSITIONAL SLOPES
- 049 PHASE I CORE ID
- 102* PHASE II CORE ID

0 0.8 1.6 Miles

GRAPHIC SCALE

PASSAIC RIVER
HACKENSACK RIVER
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
PERIPHERAL DITCH
NEWARK BAY CDF (CELL 1S)
SOUTH ELIZABETH CHANNEL
ELIZABETH RIVER
MORSES CREEK
PILES CREEK
GOETHALS BRIDGE
ARTHUR KILL
PRALLS ISLAND
SHOOTERS ISLAND
BAYONNE BRIDGE
CONRAIL BRIDGE REMNANTS
KILL VAN KULL

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. THE GEOMORPHIC AREAS SHOWN ARE CONSISTENT WITH THOSE PRESENTED IN THE PHASE II RIWP (TIERRA 2007).
4. REFERENCES:
   A. TIERRA. 2007. NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION WORK PLAN, SEDIMENT SAMPLING AND SOURCE IDENTIFICATION PROGRAM, NEWARK BAY, NEW JERSEY, PHASE II, REVISION 2, AMENDMENT 1. NOVEMBER.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

PHASE I AND PHASE II SEDIMENT COLLECTION LOCATIONS

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FIGURE
2-1

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Newark Bay (B0009989.0016.00004)
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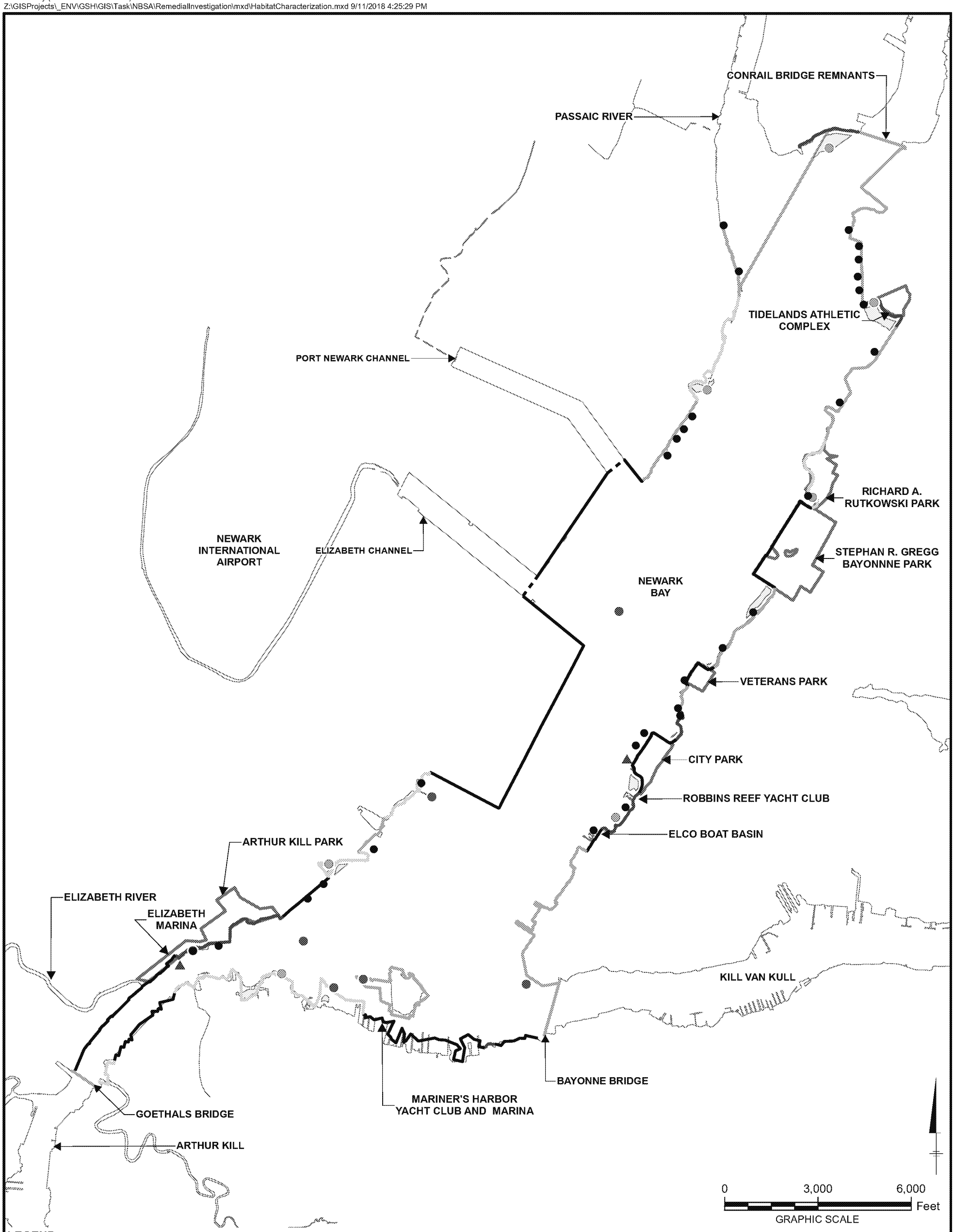

LEGEND:

- BIRD NEST LOCATION
- MAMMAL OBSERVATION
- DISCHARGE PIPE OBSERVATION
- BOAT RAMP
- NEWARK BAY STUDY AREA BOUNDARY
- SHORELINE
- UNDERGROUND TRIBUTARY
- INTERTIDAL AREA
- PARKS AND RECREATIONAL AREAS
- OBSERVED SHORELINE HABITAT:
  - BULKHEAD
  - MIXED INTERTIDAL
  - RIPRAP
  - VEGETATION

NOTES:

1. THE INTERTIDAL AREAS SHOWN ARE CONSISTENT WITH THOSE PRESENTED IN THE PROBLEM FORMULATION (TIERRA 2013) AND VERIFIED DURING THE RECONNAISSANCE SURVEY (TIERRA 2015).
2. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA-APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS, BUT MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
3. OBSERVATIONS MADE IN 2013 REGARDING BIRD NEST LOCATIONS, MAMMALS, DISCHARGE PIPES, INTERTIDAL AREAS, BOAT RAMPS, AND SHORELINE HABITAT (TIERRA 2015).
4. REFERENCES:
   A. TIERRA. 2013. FINAL NEWARK BAY STUDY AREA PROBLEM FORMULATION. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT.
   B. TIERRA. 2015. NEWARK BAY STUDY AREA RECONNAISSANCE SURVEY REPORT. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. APRIL.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SHORELINE HABITAT CHARACTERIZATION

Glenn Springs Holdings, Inc.
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FIGURE
2-2

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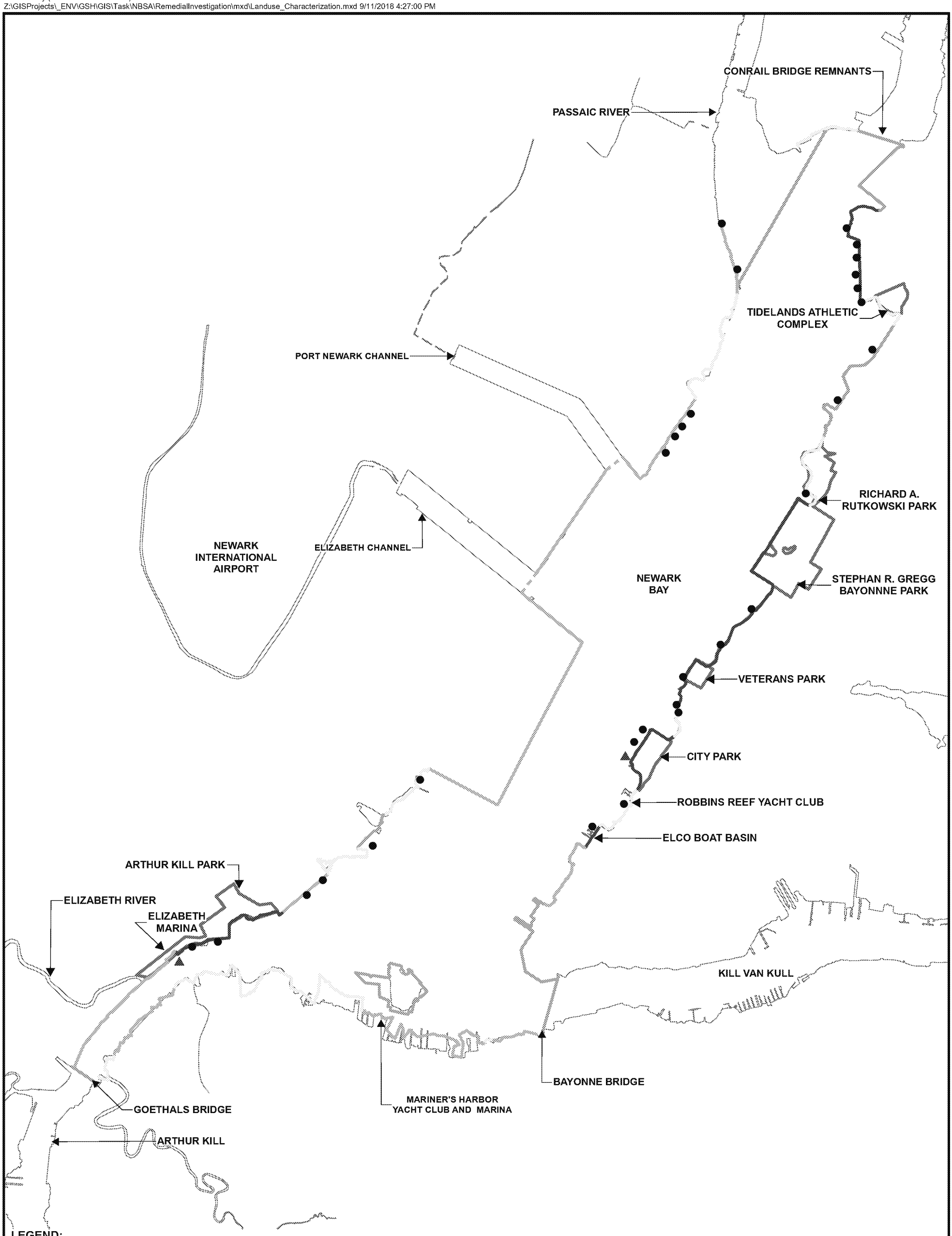

LEGEND:

- DISCHARGE PIPE OBSERVATION
- BOAT RAMP
- NEWARK BAY STUDY AREA BOUNDARY
- SHORELINE
- UNDERGROUND TRIBUTARY
- PARKS AND RECREATIONAL AREAS

OBSERVED SHORELINE USE:

- DISTURBED UPLANDS
- HABITAT
- HABITAT/RECREATIONAL
- INDUSTRIAL/COMMERCIAL
- RECREATIONAL
- RESIDENTIAL

0 3,000 6,000 Feet
GRAPHIC SCALE

NOTES:

1. THE NEWARK BAY STUDY AREA BOUNDARY WAS USEPA-APPROVED AND UTILIZED IN THE PHASE I, II, AND III SEDIMENT INVESTIGATIONS, BUT MAY BE CHANGED BY USEPA FOR FUTURE INVESTIGATIONS UNDER THE RI/FS.
2. DISCHARGE PIPE OBSERVATIONS SHOWN DO NOT REPRESENT COMPREHENSIVE INVENTORY OF DISCHARGE PIPES LOCATED ALONG THE SHORELINE.
3. OBSERVATIONS MADE IN 2013 REGARDING SHORELINE USE (TIERRA 2015).
4. REFERENCES:
   A. TIERRA. 2015. NEWARK BAY STUDY AREA RECONNAISSANCE SURVEY REPORT. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. APRIL.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SHORELINE HUMAN USE CHARACTERIZATION

Glenn Springs Holdings, Inc.
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FIGURE
2-3

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
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Z:\GISProjects_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\Overall Crab Clam Sediment Sampling Locations.mxd 9/11/2018 4:27:52 PM

LEGEND:

- CLAM AND SEDIMENT SAMPLING LOCATION
- INTERTIDAL CRAB SAMPLING LOCATION
- CRAB ZONE SAMPLING LOCATION
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- GEOGRAPHIC ZONE BOUNDARY

PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
SHOOTERS ISLAND
NEWARK BAY CENTRAL
NEWARK BAY NORTH
NEWARK BAY SOUTH
KILL VAN KULL

122B 122C 122A 122
123A 123B 133 133 123
132A 132B 132
124 124
125 125
126
127A 127 127B
131B 131A 131
130 130
135
129 129
134 134

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. THE GRAY SQUARES REPRESENT LOCATIONS WHERE CRAB TRAPS WERE PLACED FOR THE COLLECTION OF CRABS FOR THE ZONE SAMPLES. THE COMPOSITE CRAB ZONE SAMPLES WERE NOT GEOREFERENCED AND ARE NOT SHOWN ON THIS FIGURE.

0 2,500 5,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

CRAB, CLAM, AND SEDIMENT SAMPLING LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-4

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Newark Bay (B0009989.0061.00004)
Z:\GISProjects_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\FishSamplingLocs_2014Fall.mxd 9/11/2018 9:43:25 AM

LEGEND:

- EEL POT
- MINNOW TRAP
- SEINE
- TRAWL*
- TRAWL LINE
- GILLNET
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- GEOGRAPHIC ZONE BOUNDARY

PIERSONS CREEK

PORT NEWARK CHANNEL

NEWARK BAY NORTH

ELIZABETH CHANNEL

NEWARK LIBERTY INTERNATIONAL AIRPORT

NEWARK BAY CDF (CELL 1S)

NEWARK BAY CENTRAL

PERIPHERAL DITCH

SOUTH ELIZABETH CHANNEL

NEWARK BAY

NEWARK BAY SOUTH

KILL VAN KULL

SHOOTERS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. * LOCATIONS WHERE START AND END COORDINATES WERE NOT RECORDED.

0 2,500 5,000 Feet

GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

FISH SAMPLING LOCATIONS - FALL 2014

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE 2-5

ED_014250_00000231-00055

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Newark Bay (B0009989.0061.00004)
Z:\GISProjects_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\FishSamplingLocs_2015Spring.mxd 9/11/2018 9:44:48 AM

LEGEND:

- ANGLING-DRIFT
- EEL POT
- TROTLINE
- ANGLING-TROLL
- GILLNET
- TRAWL
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- GEOGRAPHIC ZONE BOUNDARY

PIERSONS CREEK

PORT NEWARK CHANNEL

NEWARK BAY NORTH

ELIZABETH CHANNEL

NEWARK LIBERTY INTERNATIONAL AIRPORT

NEWARK BAY CDF (CELL 1S)

NEWARK BAY CENTRAL

PERIPHERAL DITCH

SOUTH ELIZABETH CHANNEL

NEWARK BAY

NEWARK BAY SOUTH

KILL VAN KULL

SHOOTERS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).

0 2,500 5,000 Feet

GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

FISH SAMPLING LOCATIONS - SPRING/SUMMER 2015

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-6

ED_014250_00000231-00056

City: Citrix Div/Group: IM/DV Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Newark Bay (B0009989.0061.00004)
Z:\GISProjects_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\FishSamplingLocs_2016Spring.mxd 9/11/2018 9:45:27 AM

LEGEND:

- GILLNET
- TRAWL
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY
- GEOGRAPHIC ZONE BOUNDARY

PIERSONS CREEK

PORT NEWARK CHANNEL

NEWARK BAY NORTH

ELIZABETH CHANNEL

NEWARK LIBERTY INTERNATIONAL AIRPORT

NEWARK BAY CDF (CELL 1S)

NEWARK BAY CENTRAL

PERIPHERAL DITCH

SOUTH ELIZABETH CHANNEL

NEWARK BAY

NEWARK BAY SOUTH

KILL VAN KULL

SHOOTERS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).

0 2,500 5,000 Feet

GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

FISH SAMPLING LOCATIONS - SPRING 2016

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-7

CITY: Citrix DIV/GROUP: IM/DV Created By: K. Sinsabaugh Last Saved By: ksinsabaugh
Newark Bay (B0009989.0061.00004)
Z:\GISProjects_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\SQTSedimentSamplingStations.mxd 9/11/2018 4:36:17 PM

LEGEND:

- CLAM AND SEDIMENT SAMPLING LOCATION
- SURFACE WATER COLLECTION LOCATION

ANALYSES
- BHHRA
- SQT/PW
- SQT/PW+Bio
- SQT/PW+BHHRA
- SQT/PW+Bio+BHHRA

GEOMORPHIC AREAS
- NAVIGATION CHANNELS
- SUBTIDAL FLATS
- TRANSITIONAL SLOPES
- INTERTIDAL AREAS
- POTENTIAL HUMAN-SEDIMENT CONTACT LOCATION
- SHORELINE
- UNDERGROUND TRIBUTARY
- GEOGRAPHIC ZONE BOUNDARY

GEOMORPHIC AREAS:
- HISTORICALLY DISTURBED SUBTIDAL FLATS
- INDUSTRIAL WATERFRONT
- INTERTIDAL AREA
- NAVIGATION CHANNEL
- PORT CHANNEL
- SUBTIDAL FLATS
- TRANSITIONAL SLOPES

OBSERVED SHORELINE USE:
- DISTURBED UPLANDS
- HABITAT
- HABITAT/RECREATIONAL
- INDUSTRIAL/COMMERCIAL
- RECREATIONAL
- RESIDENTIAL

0 2,500 5,000 Feet
GRAPHIC SCALE

CONRAIL BRIDGE REMNANTS
HACKENSACK RIVER
PASSAIC RIVER
PIERSONS CREEK
PORT NEWARK CHANNEL
INDUSTRIAL/COMMERCIAL ACCESS AREA
NEWARK BAY NORTH
LEHIGH VALLEY RAIL ROAD BRIDGE
NEW JERSEY TURNPIKE
RICHARD A RUTOWSKI PARK
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
VETERANS PARK
TRAILER PARK
NEWARK BAY CENTRAL
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
NEWARK BAY SOUTH
ARTHUR KILL
KILL VAN KULL
BAYONNE BRIDGE
SHOOTERS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. AERIAL PHOTOS DATED 2015 (ESRI CLOUD IMAGERY).
3. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
4. THE GEOMORPHIC AREAS SHOWN ARE CONSISTENT WITH THOSE PRESENTED IN THE CSM (GSH 2018).
5. SQT REPRESENTS THREE ANALYSES: SEDIMENT CHEMISTRY, BENTHIC INVERTEBRATE COMMUNITY, AND TOXICITY TESTING WITH L. PLUMULOSUS (10-DAY AND 28-DAY).
6. SURFACE WATER WAS NOT A TARGETED SAMPLING MATRIX. SURFACE WATER WAS COLLECTED AND USED IN THE FIELD FACILITY FOR THE SHIPMENT OF SEDIMENT FOR POREWATER ANALYSES.
7. GEOMORPHIC AREA DESIGNATIONS FOR EACH SAMPLING LOCATION ARE BASED ON THE FIELD-COLLECTED GEOGRAPHIC COORDINATES OF THE ACTUAL SAMPLING LOCATIONS AS RECORDED DURING SEDIMENT COLLECTION ACTIVITIES. (GSH 2017)
8. REFERENCES:
   A. GSH. 2018. CONCEPTUAL SITE MODEL. NEWARK BAY STUDY AREA. REVISION 2. AUGUST.
   B. GSH. 2017. SEDIMENT QUALITY TRIAD AND POREWATER FIELD REPORT. NEWARK BAY STUDY AREA. BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT. REVISION 1. SEPTEMBER.

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SQT AND POREWATER SAMPLING STATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-8

City: SYR Div/Group: IM/DV Created By: ksinsabaugh Last Saved By: ksinsabaugh
Newark Bay (B0009989.0045.00006)
Z:\GISProjects_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\PhIIISedimentCollectionLocations.mxd 9/11/2018 9:46:06 AM

LEGEND:

- PHASE III SEDIMENT SAMPLING LOCATION
- NAVIGATION CHANNEL
- SHORELINE
- UNDERGROUND TRIBUTARY
- NEWARK BAY STUDY AREA BOUNDARY

PROPOSED USEPA SUBUNIT

- 1
- 2
- 3
- 4
- 5
- 6

PASSAIC RIVER
PIERSONS CREEK
PORT NEWARK CHANNEL
ELIZABETH CHANNEL
NEWARK LIBERTY INTERNATIONAL AIRPORT
NEWARK BAY CDF (CELL 1S)
PERIPHERAL DITCH
SOUTH ELIZABETH CHANNEL
KILL VAN KULL
SHOOTERS ISLAND
ARTHUR KILL
PRALLS ISLAND

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).

0 3,000 6,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

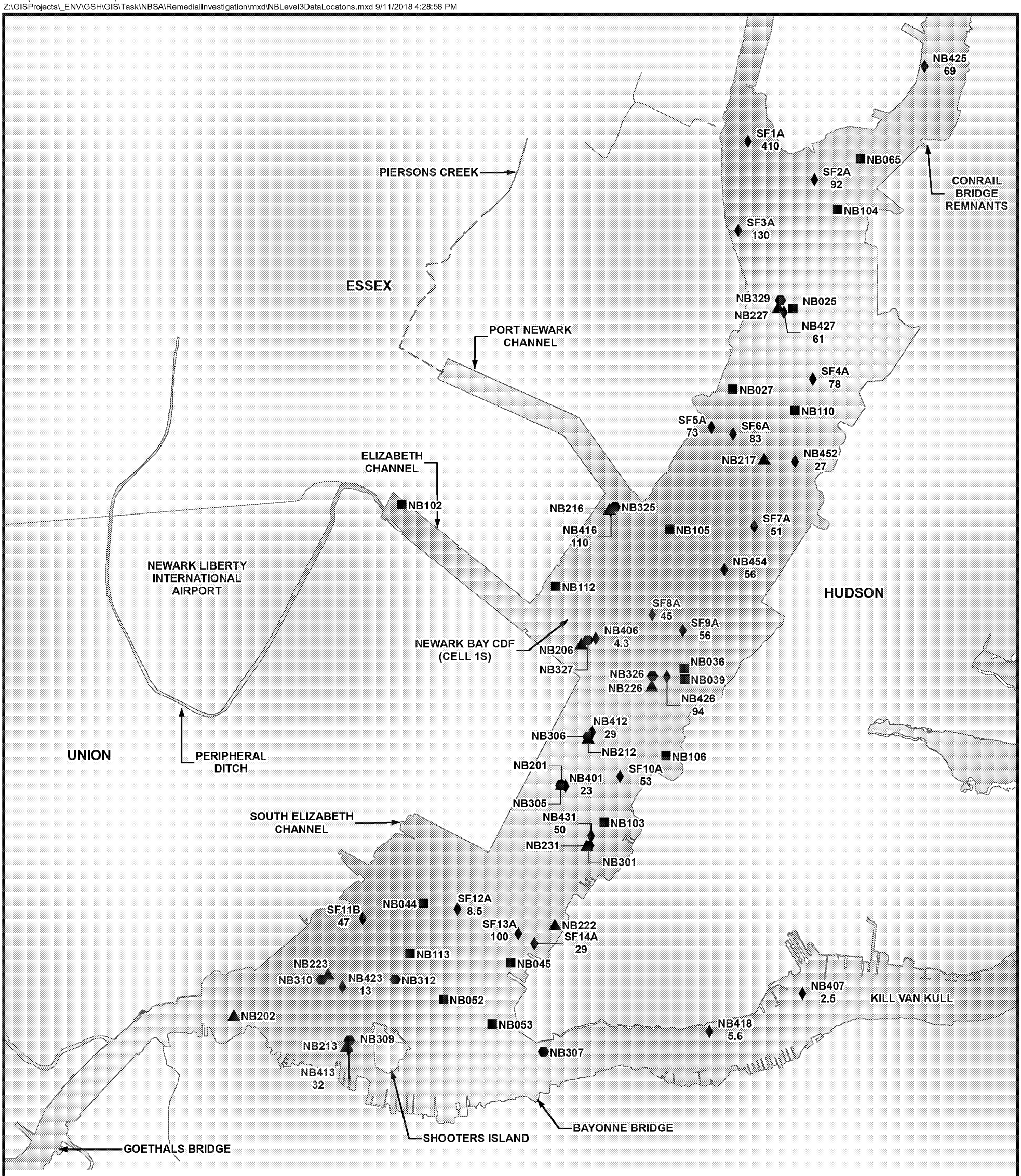
PHASE III SEDIMENT COLLECTION LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE 2-9

ED_014250_00000231-00059

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Tierra (B0009989.0061.00002)
Z:\GISProjects_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\NBLevel3DataLocatons.mxd 9/11/2018 4:28:58 PM



LEGEND:

- 2013 POST-HURRICANE SANDY SAMPLING LOCATION
- 10 DAY SURVIVAL FOR *AMPELISCA ABDITA* REMAP 1993
- 10 DAY SURVIVAL FOR *AMPELISCA ABDITA* REMAP 1998
- 10 DAY SURVIVAL FOR *AMPELISCA ABDITA* REMAP 2003
- SHORELINE
- UNDERGROUND TRIBUTARY

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. FOR INFORMATION ABOUT THE DATA USABILITY LEVELS AND THEIR APPLICABILITY, PLEASE REFER TO SECTION 2 OF THE REPORT.

0 3,000 6,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

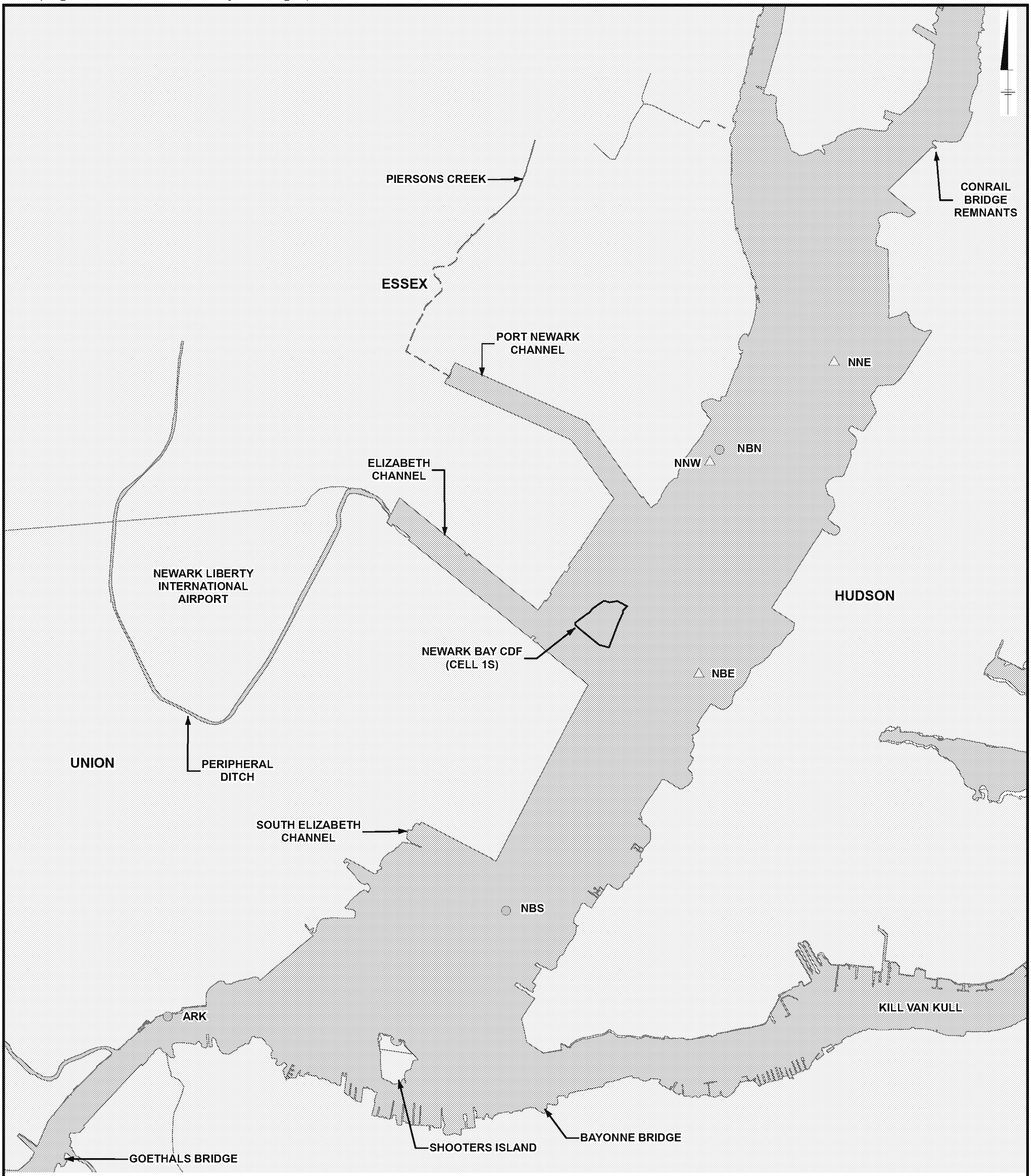
NEWARK BAY LEVEL 3 DATA LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-10

ED_014250_00000231-00060

City: SYR Div/Group: IM Created By: K. SINSABAUGH Last Saved By: ksinsabaugh
Tierra (B0009989.0025.00001)
Z:\GISProjects_ENV\GSH\GIS\Task\NBSA\RemedialInvestigation\mxd\SW_SampleLocs.mxd 9/11/2018 4:28:28 PM



LEGEND:

- PHYSICAL AND CHEMICAL SURFACE WATER SAMPLE LOCATION
- CHEMICAL ONLY SURFACE WATER SAMPLE LOCATION
- SHORELINE
- UNDERGROUND TRIBUTARY

NOTES:

1. HORIZONTAL DATUM: NEW JERSEY STATE PLANE COORDINATE SYSTEM, NAD83.
2. SHORELINE IS DIGITIZED FROM AERIAL PHOTO DATED JULY 2002 (INTRASEARCH, ENGLEWOOD, CO).
3. CHEMICAL DATA WERE COLLECTED DURING THREE FIELD SAMPLING EVENTS IN AUGUST 2011, FEBRUARY 2012, AND MARCH 2012 BY THE COOPERATING PARTIES GROUP IN ACCORDANCE WITH THE QUALITY ASSURANCE PROJECT PLAN AND FIELD SAMPLING PLAN ADDENDUM (AECOM 2011).
4. PHYSICAL DATA WERE COLLECTED IN APRIL - JUNE 2010 BY THE COOPERATING PARTIES GROUP IN ACCORDANCE WITH THE QUALITY ASSURANCE PROJECT PLAN/FIELD SAMPLING PLAN ADDENDUM (AECOM 2010).
5. REFERENCES:
   A. AECOM. 2011. QUALITY ASSURANCE PROJECT PLAN/FIELD SAMPLING PLAN ADDENDUM, REMEDIAL INVESTIGATION WATER COLUMN MONITORING/SMALL VOLUME CHEMICAL DATA COLLECTION, LOWER PASSAIC RIVER RESTORATION PROJECT. REVISION 2.
   B. AECOM 2010. REMEDIAL INVESTIGATION WATER COLUMN MONITORING/PHYSICAL DATA COLLECTION FOR THE LOWER PASSAIC RIVER, NEWARK BAY AND WET WEATHER MONITORING: LOWER PASSAIC RIVER RESTORATION PROJECT. QUALITY ASSURANCE PROJECT PLAN. REVISION 5.

0 3,000 6,000 Feet
GRAPHIC SCALE

DIAMOND ALKALI SUPERFUND SITE
NEWARK BAY STUDY AREA REMEDIAL INVESTIGATION
REMEDIAL INVESTIGATION REPORT

SURFACE WATER SAMPLE LOCATIONS

Glenn Springs Holdings, Inc.
A subsidiary of Occidental Petroleum

FIGURE
2-11

ED_014250_00000231-00061

Arcadis U.S., Inc.

8 South River Road

Cranbury, New Jersey 08512

Tel 609 860 0590

Fax 609 860 0491

www.arcadis.com